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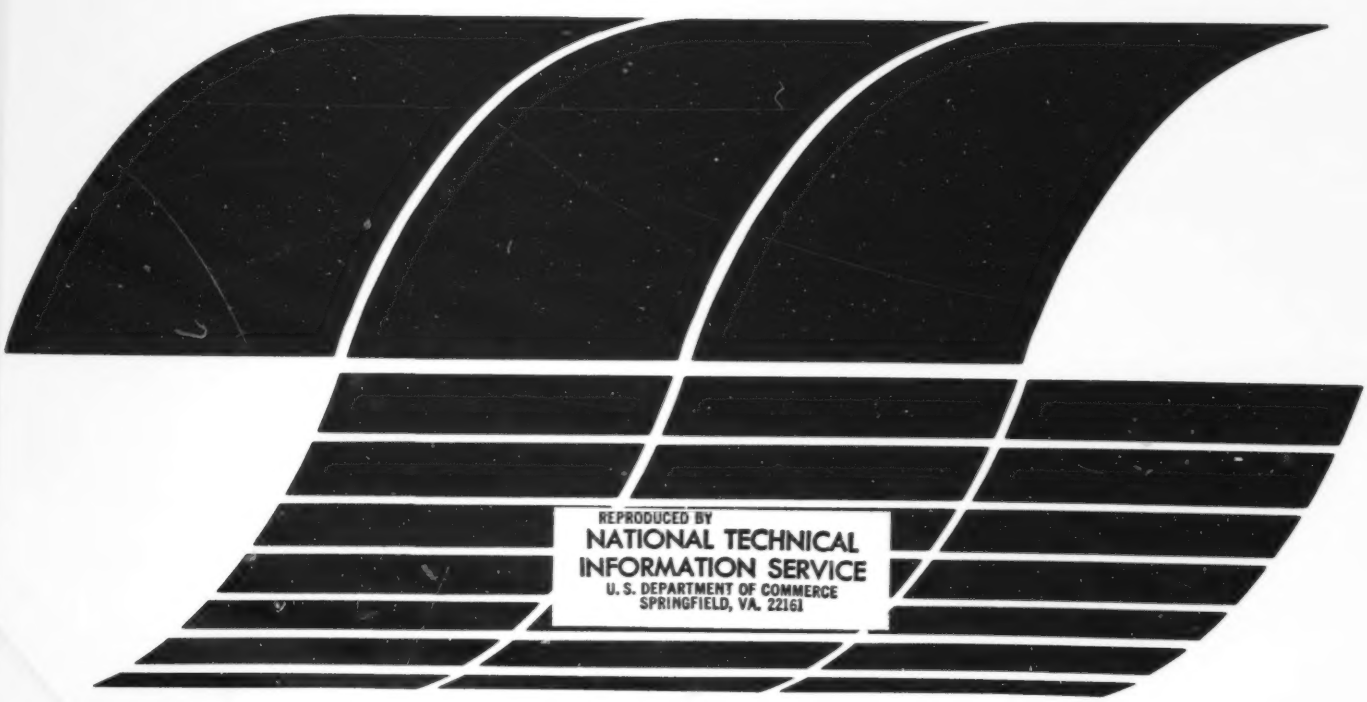

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16. ABSTRACT

A fugitive dust sampling program was conducted at Anvil Points, Colorado, site of the Paraho mining and oil shale retorting operations. High-volume samplers were used extensively for fugitive dust collection, and 175 total suspended particulate calculations are reported for measurements made at the mine adits, the haul road, raw shale crushing area, and the spent shale transfer area. Supporting meteorological data is also given as well as background dust measurements. Particulate size distribution calculations were derived from 36 cascade impactor samples at the above locations.

Elemental chemical analysis results are reported for eighteen elements from each of twenty selected high-volume sampler collections. In addition, twenty-six samples were extracted for organic content. The extractions were then fractionated by the EPA/IERL Level 1 method, and eight organic classification fractions are quantitatively given.

The significance of these findings is summarized, and recommendations for work are stated.

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FUGITIVE DUST AT THE PARAHO OIL SHALE DEMONSTRATION RETORT AND MINE

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

New synthetic fuel processes under development need to be characterized prior to commercialization, so that pollution control needs can be identified and control methods can be integrated with process designs. This sampling and analysis program for fugitive dust, conducted at the Paraho oil shale demonstration plant, represents a significant advance in oil shale extraction and handling characterization. The work reported in this document will serve as a guide for the determination of fugitive dust sampling and analysis priorities in future oil shale programs. For further information contact the Resource Extraction and Handling Division.

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ABSTRACT

A fugitive dust sampling program was conducted at the Anvil Points, Colorado site of the Paraho mining and oil-shale retorting operation. High-volume samplers were used extensively for fugitive dust collection, and 175 calculations for total suspended particulate were reported for measurements made at the mine adits, haul road, raw shale crushing area, and spent shale transfer area. Supporting meteorological data are also given, as well as background dust measurements. Particulate size distribution calculations were derived from 36 cascade impactor samples at the above locations.

Elemental chemical analysis results were reported for 19 elements from each of 20 selected high-volume sample collections. In addition, 26 samples were extracted for organic content. The extractions were then fractionated by the EPA/IERL Level 1 method, and eight organic classification fractions were quantitatively given. The significance of these findings is summarized, and recommendations for work are stated.

This report was submitted in fulfillment of Contract No. 68-02-2560 by TRW Environmental Engineering Division under the sponsorship of the U.S. Environmental Protection Agency. Chemical analyses of particulate samples were subcontracted to Denver Research Institute and CDM/Acculabs. The report covers the period of August 17, 1977 to January 31, 1978, and work was completed as of September 1, 1978.

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The close cooperation and assistance of the Development Engineering, Inc. in the conduct of the fugitive dust sampling program is gratefully acknowledged. Recognition is also due to Laramie Energy Technology Center (Department of Energy), The Paraho site administrator, for their continuing support of interagency environmental study programs.

SECTION 1

INTRODUCTION

PROGRAM OBJECTIVES AND UTILITY BACKGROUND

An environmental assessment of oil shale extraction processes was recently completed by TRW for the USEPA. As part of the work plan for the assessment, TRW conducted a sampling and analysis program at the Paraho oil shale demonstration plant in Anvil Points, Colorado, in 1976.[1] A strong recommendation resulting from this prior work was that a comprehensive fugitive dust survey should be conducted at the Anvil Points site, in anticipation of future studies for dust control related to mining, crushing, and material handling operations.

Aims of the Test Program

The program objectives included: 1) determining the sources of fugitive dust and the contributions of these sources over and above natural background dust concentrations; 2) noting related meteorological characteristics; 3) quantitatively evaluating the total suspended particulates (TSP) at various distances from the dust sources; and 4) determining particulate size distribution at the TSP measurement locations.

In addition to the mass measurements, chemical composition of particulate matter was also defined as a program measurement objective. Both inorganic elemental analysis and organic classifications were sought. These constituent analyses helped to characterize particulate matter which fell into the breathable dust category, and they also provided useful clues concerning the particulate-generating sources.

Program Management

The fugitive dust sampling program was done in close cooperation with Developing Engineering, Inc. (DEI), the operator of the Paraho site. A subcontract was let to DEI for program support, transportation on site, facilities

[1] Sampling and Analysis Research Program at the Paraho Oil Shale Demonstration Plant, EPA 600/7-78-065; also, Executive Briefing; Environmental Sampling of the Paraho Oil Shale Retort Process at Anvil Points, USEPA Technology Transfer, EPA-625/9-77-002.

usage and data review. A major subcontract was also released to Denver Research Institute for laboratory analysis of organic extractions from selected particulate samples. A purchase order was placed with CDM/Acculabs for inorganic elemental analysis. The efforts of these participants were coordinated with TRW sampling and analysis work to assure the USEPA of a rapid completion of the project with a minimum of delays. Program information requirements and various samples were scheduled for release to the various participants. Laramie Energy Technology Center (Department of Energy), the lease administrator for the Anvil Points site, was also advised of the program activities.

Limitations and Uses of the Test Results

The data obtained from the crushing and retorting operations are unique to the Paraho Oil Shale Demonstration Plant. Because much of the equipment and many of the operating procedures used at Anvil Points would probably not be employed in a commercial venture, data pertaining to particulate and dust quantities in the site vicinity cannot be compared to those from a full-scale Paraho-type operation. The mining operations are possibly the closest model of a commercial facility. A detailed discussion of the Anvil Points equipment and operating procedures is developed more fully in this section.

DESCRIPTION OF THE PARAHO PROCESS AND SITE

Underground Mining and Crushing

The mine at Anvil Points is a room and pillar operation mining the Mahogany Ledge of the Green River Formation, at an altitude of approximately 2440 meters (8000 ft). Mined shale is trucked 8.8 kilometers (5.5 mi) by road down to the processing area (Figure 1).

At the plant site the mined shale is processed through the primary and secondary circuits of the crushing and screening plant, to produce a feed of approximately minus 7.6 centimeters (3 in) to plus 6 millimeters (1/4 in) in size, which is sent to storage bins. The jaw-type crushing equipment is government-furnished Navy surplus, and is unenclosed. The 10-15% fines from the screening plant are stock-piled.

The screening operations are enclosed in existing buildings. Fugitive dust in the interior air is collected in baghouse filters. After the filtering fines are removed and stockpiled.

Semi-Works Retort

The minus 7.6 centimeters (3 in) to plus 6 millimeters (1/4 in) product from the crushing and screening plant is lifted and transferred by an inclined belt to the top of the retort. The inclined and lateral transfer belts are not tightly enclosed.

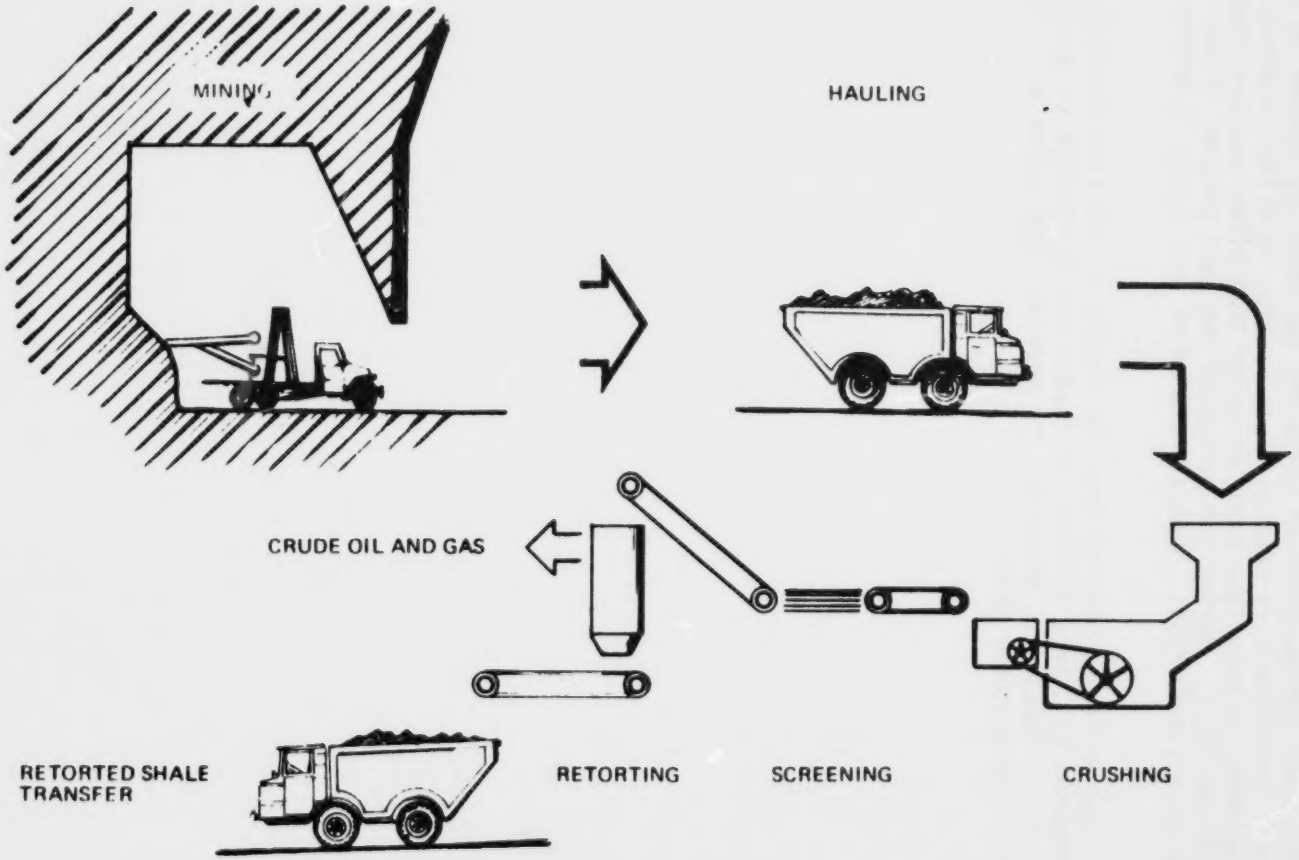

Figure 1. Schematic of Anvil Points mining and material handling operations.

Probably the most representative piece of equipment at the Anvil Points plant site is the Paraho semi-works retort itself, which is specifically designed to use the same configuration of solid and gas handling systems as a full-scale plant. This retort is capable of operating, in either a direct or indirect heating mode, at mass feed rates of up to 3423 kilograms/hour/square meter (700 lbs/hr/sq. ft.). During the period of the test program it was operated in the direct mode only. Typical feed rates were about 10 metric tons/hour.

Spent retorted shale was removed from the bottom of the kiln at about 150°C 230°C and transferred by a belt conveyor to trucks for conveyance to an off-site vegetation study location. Normally, the conveyor dump point would be at the retorted shale disposal area.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

PARTICULATE PHYSICAL MEASUREMENTS

Total suspended particulate (TSP) measurements of fugitive dust can be effectively carried out with high-volume samplers in the vicinity of oil shale mining and handling operations. Measurements conducted at the Anvil Points mine adits appeared to be the most definable, since fugitive dusts from mining, blasting, and vehicular exhausts were confined. Measurements in open areas (haul road, retorted shale transfer, crushing) will vary considerably from one high-volume sampler to the next, implying that a single sample source cannot supply data which is typical for the area. A number of samplers must be used, to allow for random variations in dust concentrations under varying wind and terrain conditions. The sampler configuration used in this study (two - downwind, one - upwind) is probably a minimum choice to provide useable TSP statistics.

TSP data included in this report appeared to be credible with sample volumes as low as 30 cubic meters, while sample volumes of 15 cubic meters tended to give results that were out of line with larger sample volumes. Although the data are useful measures of ambient dust concentrations at ground level, they are too scattered or biased to be used for very accurate dispersion or source emission estimates.

Particle size separations were done with cascade impactors mounted at the intake of selected high-volume samplers. The method was not difficult to implement, but the interpretation of the raw data left some key questions unanswered. The assumption that the high-volume filters can be treated as a final impactor stage is very questionable, and it is strongly recommended that comparative studies be initiated with uniform dust sources. Evaluating cascade impactor performance versus optical sizing techniques indicated that particle bounce errors were significant.

PARTICULATE CHEMICAL ANALYSIS

Elemental analyses of the particulate samples from various areas appear to be similar to the elemental concentrations of oil shale, even though raw shale dust, retorted shale dust, and haul road dust were collected. The methods used for the analysis of each constituent were selected for accuracy and were time-consuming. For any future work involving large numbers of fugitive dust samples, spark-source mass spectrometry is recommended as a much faster analysis method, even though analysis accuracy would be limited to a factor of two to three. Millipore high-volume filters would be better than paper filters for these samples, since paper is difficult to stabilize for weighing.

Separation of the organic extracts was effective for providing preliminary sample characterization, using the Level 1 liquid chromatography method. It is strongly recommended that future analyses of fugitive dust samples include complete infrared spectroscopy of each of the separated chromatographic fractions. In order to do this without interference from contaminants, the high-volume filters should be solvent-extracted before use in the field. Although the Level 1 fractionation is a screening technique rather than a detailed analysis procedure, it was able to provide some strong evidence that equipment and explosives used in mining activities generate particulates, as well as raw shale dust.

FUTURE WORK

Fugitive dust measurements should be continued at other oil shale extraction sites as opportunities occur. The coverage of sampling locations should be extensive, since considerable statistical variations of sample results are expected. If the dust measurements are to be used for source emission estimates, then the placement of high-volume samplers must be selected to relate to the particular diffusion model used for these estimates. Cascade impactors for particulate size distribution measurements should be preceded by an inlet cyclone to collect particles above 5 micron size, and some optical size scanning should be done in parallel. Finally, samples taken for organic analyzes should be as large as many of the samples used in this survey (1 gram or larger) to minimize weighing errors, and high-volume fiberglass filters should be solvent-extracted prior to use to remove silicon oils.

SECTION 3

SAMPLING AND ANALYSIS PROCEDURES

Site Survey and Preparation

The TRW Task Manager visited the Anvil Points site with the Technical Project Monitor (TPM) and other EPA personnel. A survey was made of the mining and oil shale handling operations, to determine sources of fugitive dust, and candidate locations for collection devices. Visual observations of dust-generating operations and local wind behavior were especially useful in preparing the equipment plan and choice of methodology. Support services and facilities were arranged with the site operator, Development Engineering Inc. (DEI). Services included access to line power wherever feasible, and transportation for test team personnel.

Test Plan and Equipment Selection

The principal dust collection devices were high-volume samplers (General Metal Works Models 2000 and 2310). These were supplemented, as required by the test plan, by cascade impaction samplers (Sierra Instruments, Model 235) determining particle size distribution. The sampling locations and area designations are given in the local contour map (Figure 2) and the test matrix (Table 1) respectively. The testing locations and periods of operation were reviewed with representatives from DEI to assure that mining and extraction operations would not be affected in any way by the sampling activity. As indicated in Table 1, dust collection took place in the vicinity of mining, hauling, crushing and discharging operations. The Anvil Points mine ventilation system consists of fresh air forced through one adit, circulation to the back of the mine, and exhaust from two remaining adits. High-volume samplers were used at the mine mouth for the fugitive dusts carried out in the exhaust air through the two adits. Except for the mine, meteorological instrumentation was also provided at each collection location to continuously record wind direction and velocity. The instrumentation is described in the equipment list in Table A-8. At the remote haul road locations, portable generators were used to power the high-volume units.

The sampling schedule was arranged for a continuous four-week effort, in an attempt to include some statistical variation of sample characteristics during the course of the program. As indicated by the test matrix (Table 1), measurements in the vicinity of the crusher were not emphasized, because the equipment was obsolete, and was being used only as an expedient during the limited duration research and development program conducted by DEI.

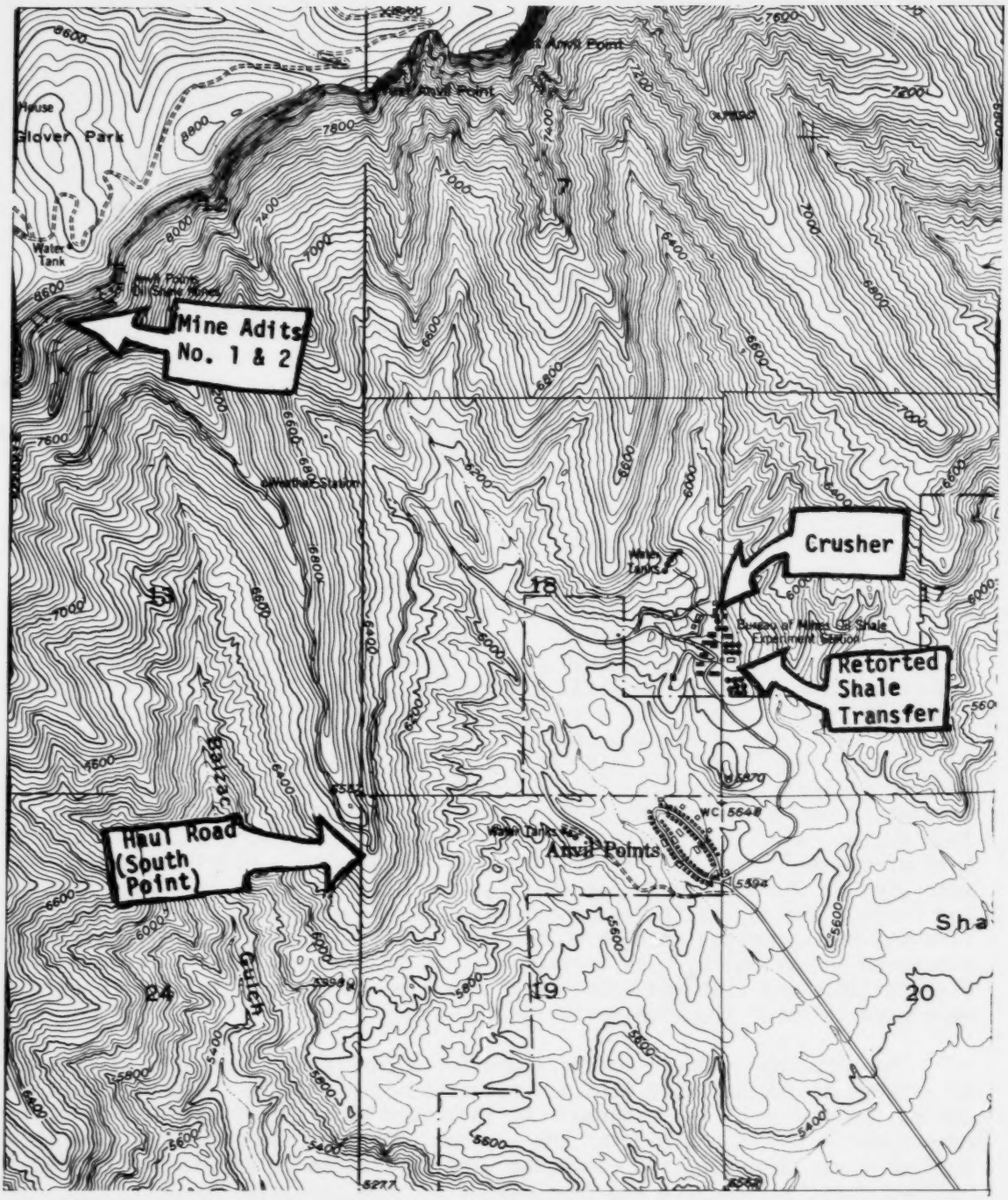

Figure 2. General locations of fugitive dust sampling.

TABLE 1. TEST MATRIX

Sources	No. sampling locations	Total No. samples for TSP	Total No. size distribution	Total No. inorganic and organic analyses
				(Each category)
Mine adits	2	40	8	4
Haul road	3	90	12	6
Crushing area	3	15	6	3
Spent shale transfer	3	30	12	6

The mining and hauling operations were given considerable attention, since these activities are similar to that expected of full-scale operations.

Sampling Program Execution

Upon notification of a starting date by the TPM, the field sampling team was placed on site within a week. At the same time, final support arrangements were made with DEI personnel.

The required complement of high-volume samplers, portable generators, and meteorological instruments were deployed at the Anvil Points site according to the approved final test plan. High-volume samplers were positioned at the retorted shale transfer area (Figure 3) and adjacent to the haul road (Figure 4). The collectors located near each source consisted of a one upwind-two downwind configuration, with the exception of the mine mouth. As in most mountain valley terrains, there was a strong upslope wind during midday, and a downslope wind in the evening and early morning hours. However, since local wind patterns were variable, close surveillance was required to determine when a collector was in an upwind or downwind position, and manual switchovers were done as required. An automatic switch-over controller actuated by a wind direction detector failed to operate at the site.

Close operational supervision was required, to ensure that sample collections were coordinated with dust-generating activity. Very close coordination with DEI personnel was required to achieve this objective. The period

Figure 3. High-vol samplers at retorted shale disposal area.

Figure 4. High-vol samplers and meteorological station near haul road.

of sampling varied, depending on the amount of sample desired and proximity to a source. Although a nominal one-hour sampling period was usually sufficient, rough filter weighings in the field were used to assure that sample catches were sufficiently large to provide accurate weings and analyses. The three-sampler sites had one unit upwind (approximately 20 meters) and two units downwind (approximately 10 and 50 meters, depending on the site and sample catch). The two downwind samplers were approximately on the downwind axis.

Records of mine and plant activity were kept by the field crew for each sampling site. In particular, mining activities, blasting, haul truck operations, and crushing operations were logged, since all of these activities were intermittent or variable. This information was recorded on the same data sheets as the high-volume unit records.

Data Reduction and Quality Assurance

Filters were removed from the high-volume samplers and cascade impactors after each test and sealed in polyethylene bags. The bags were placed in an envelope, with the location and field data recorded on the envelope. The basic record number for each sample was the filter sequence number, which was printed on each filter. Therefore, the results associated with each sample were directly traceable back to the filters, which were put into storage unless they were consumed in a subsequent analysis step.

As already noted, the key to assuring continued operation of both high-volume samplers and meteorological instrumentation was close surveillance by the field crew. The air flow rate through the high-volume units was recorded from rotometers at the beginning and end of each sample collection. Local temperatures and pressures were recorded to correct the average actual flow rates to standard conditions. The rotometers were calibrated against a calibrated orifice meter at the start of the field testing program.

Total suspended particulate (TSP) values for each sample collected were determined from stabilized filter weights, sample time, and corrected sampler air flow rate. Before-and-after weights were taken under controlled temperature and humidity conditions. The cascade impactor filters were weighed under controlled conditions as well, and particulate size breakdown determined from impactor calibration curves, down to about the 0.5μ (and less) cutoff. A five-stage impactor was used. Fiberglas filters were used for TSP determinations and (in some cases) subsequent organic analysis. Fiberglas filters have excellent weight stability, since water absorption is negligible. Since Fiberglas filters cannot be decontaminated well enough for good elemental analysis, Whatman paper filters were used for inorganic determinations. There is a trade-off involved in this choice, since paper filters are difficult to stabilize and the resulting net sample weights are probably less accurate than samples collected on Fiberglas.

Organic analyses require large (1 to 10 g) samples to be quantitative, especially for spent shale (which is lower in organic content then raw shale). Therefore, the sampling time for organic analysis samples was considerably longer than other samples. In some cases, the high-volume units were run overnight to collect a sufficient sample mass. Locating a sampler within a few meters of the dust source was another technique used to increase sample size. Samples weighing 10 to 20 grams were not intended for TSP calculations, since high-volume air flow characteristics are unreliable with the resistance presented by a heavy sample layer on a filter.

Meteorological data were recorded on strip charts, and average conditions were manually interpreted for each hour of operation. Wind direction and air temperature were directly recorded, while wind speed was averaged from the "wind run" trace (which is an integrated wind speed).

The final quality assurance step was data validation by comparison with similar samples. The size of the data base obtained from the test program is large enough to allow these comparisons to be useful. In some cases, for example, the appearance of insufficient sample size was confirmed by gross variances in analytical results. Accuracy estimates for analysis methods were used to determine the statistical validity of analysis results.

LABORATORY ANALYSIS METHODS

Inorganic Analysis

Nineteen elemental determinations were done (Table 2) for the number of samples indicated in the test matrix of Table 1, with the exception of two haul-road upwind sampler locations which collected no measureable dust during their period of operation. Three additional determinations were done, of samples taken in the vicinity of the screening room baghouse for comparison to other raw shale source samples.

TABLE 2. ELEMENTAL ANALYSIS GROUP

Element	Element	Element
Arsenic	Fluoride	Nickel
Aluminum	Iron	Lead
Calcium	Magnesium	Selenium
Cadmium	Manganese	Vanadium
Chromium	Mercury	Zinc
Copper	Sodium	Silicon
		Sulfur

All analytical methods were based upon standard procedures, as described in Appendix B. Although typical IERL/RTP Level 1 methods for elemental analysis employ spark source mass spectrometry, a decision was make to use standard analysis techniques in the interest of higher accuracy.

Flame-mode atomic absorption was used to determine Al, Ca, Cd, Cr, Cu, Fe, Mg, Na, Ni, Pb, and Zn. Flameless atomic absorption-graphite furnace atomization was used to determine As, Se, and V. Mercury was determined by cold vapor generation-atomic absorption. Si was determined by a colorimetric technique and F was determined by specific ion electrode. Sulfur was determined by a gravimetric method after conversion to a sulfate. Generally speaking the limits of precision were ± 10%. For sample sizes less than 0.05 grams the precision was ± 100%, and for samples less than 0.2 grams the precision was ± 50%.

Organic Analyses

Selected particulate samples were extracted for 48 hours in methylene chloride, using soxhlet extractors (Figure 5). After extraction, the extracts were reduced in volume on a rotary evaporator and then weighed to within ± 0.00003 grams. The samples were then fractionated into eight fractions, using EPA Level 1 liquid chromatography procedures.[2]

A silica gel column was prepared (as described in detail in Appendix C), and a sample was washed into the top of the column at the start of each separation. Elution was carried out using the solvents given in Table 3. The classes of organic compounds expected in each fraction eluting in the bottom are given in Table 4. The eluted fractions were allowed to go to constant weight, and final weighings were recorded to ± 30 micrograms. Silicon oils apparently left on the Fiberglass filters from the manufacturing process contaminated the samples and no doubt influenced the organic analysis results.

[2]Technical Manual for Analysis of Organic Materials in Process Streams, EPA 600/2-76-072, March 1976.

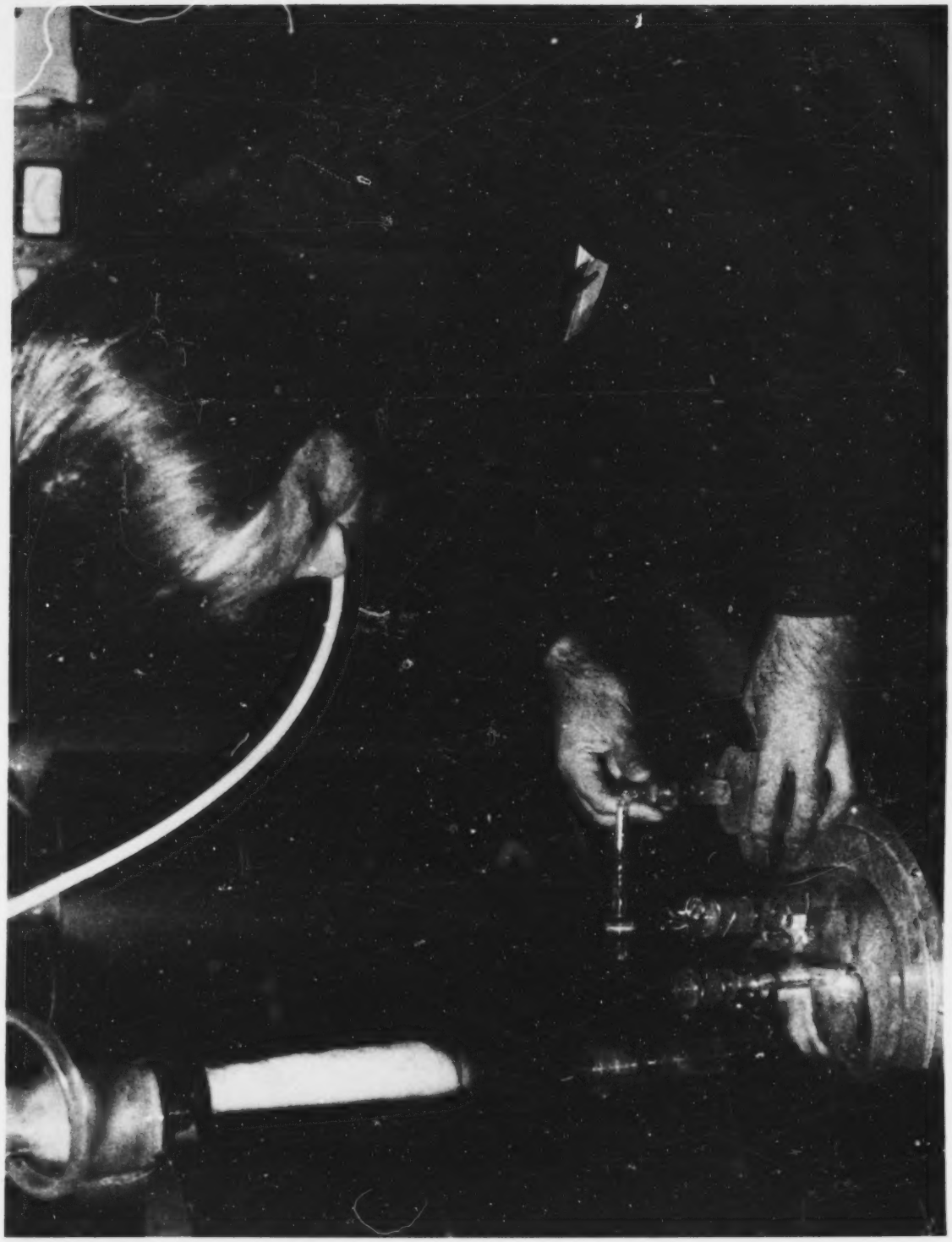

Figure 5. Extraction of samples for organic analyses.

TABLE 3. SEQUENCE AND QUANTITIES OF SOLVENTS USED FOR LIQUID CHROMATOGRAPHIC ELUTIONS

Fraction Number	Solvent	
1	25 ml	n-hexane
2	25 ml	20% methylene chloride in n-hexane
3	25 ml	50% methylene chloride in n-hexane
4	25 ml	methylene chloride
5	25 ml	5% methanol in methylene chloride
6	25 ml	20% methanol in methylene chloride
7	25 ml	50% methanol in methylene chloride
8	25 ml	methanol

TABLE 4. CLASSES OF ORGANIC COMPOUNDS REPORTEDLY[2] ELUTED IN EACH LIQUID CHROMATOGRAPH FRACTION

Fraction number	
1	Aliphatic hydrocarbons
2	Aromatic hydrocarbons Polynuclear organic materials Polychlorinated biphenols Halides
3	Esters Ethers Nitro compounds Epoxides
4	Phenols Esters Ketones Aldehydes Phthalates
5	Phenols Alcohols Phthalates Amines
6	Amides Sulfonates Aliphatic acids Carboxylic acid salts
7	Sulfonates Sulfoxides Sulfonic acids
8	Sulfonic acids

[2]Technical Manual for Analysis Organic Materials in Process Streams. EPA 600/2-76-072, March 1976.

SECTION 4

SUMMARY OF MEASUREMENT RESULTS

TOTAL SUSPENDED PARTICULATES

Total suspended particulate matter (TSP) measurements are summarized in this section, and the detailed calculations are presented in Appendix A, as are the meteorological and vehicle movement records.

Retorted Shale Transfer Area

Particulate matter concentrations are plotted in Figure 6 as milligrams per cubic meter (mg/m^3) @ 20^0 C, as measured near the point where retorted shale was transferred from a discharge conveyor to haul trucks. The downwind samplers were always north of the transfer point, as indicated by the average wind conditions indicated on the figure. The upwind sampler for background measurements was placed in the corresponding south orientation.

The high-volume samplers were located at 15-20 meters north (15-20 MN), 35 meters north (35 MN), 100 meters south (100 MS), and (for heavy sample collection only) 5 meters north (5 MN). An unexpected result was that consistantly higher concentrations were measured at 35 meters downwind than at 15 and 20 meters downwind of the source. The only other apparent contributor of dust in the vicinity was the crushing and screening operations which were always downwind of the samplers during the testing periods. A possible explanation of this result is that a sampler at 15-20 meters, having been placed at a lower elevation than the source, was missing a portion of the centerline dust concentrations. The sampler at 35 meters was at about the same elevation as the source, since the terrain was rising at this point.

TSP values ranged from 2 to 36 milligrams/cubic meters at the downwind locations, while background values were about 0.5 milligrams/cubic meters. The samples were collected for about one hour at downwind locations and two hours at upwind locations, with sample catches ranging from 100 to 1000 milligrams. Heavier samples were always found downwind. Occasional runs were made for much longer periods (20 hr) to obtain heavy samples, but TSP values obtained from these tests are not comparable to shorter sampling periods. In general, a 24-hour collection will yield a lower TSP value than that obtained from a 1-hour test, because periods of inactivity will be included in the longer test time.

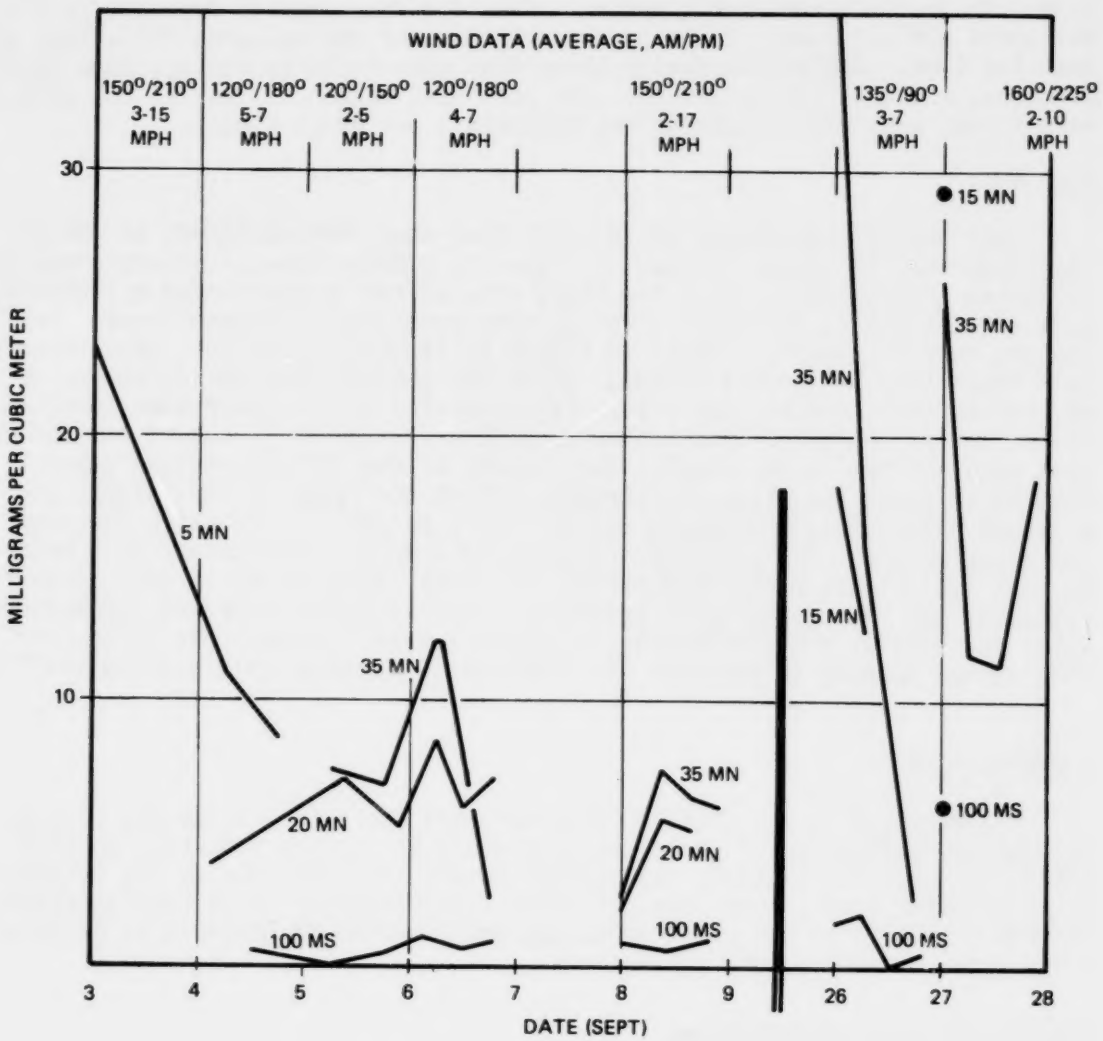

Figure 6. TSP values for retorted shale transfer area.

Mine Adits

TSP values measured at Anvil Points mine adits No. 1 and 2 are plotted in Figure 7 for five separate days in September. Concentrations varied widely from 1 to 35 milligrams/cubic meters. Sampling times varied from 0.5 to 2 hours, but there did not appear to be any correlations of the measured TSP values with sampling time. Activities during these five days included mining, dump truck movement, and (on 9/27) blasting. The peak dust concentrations at the adits were found, predictably, during the post-blast period at midday.

Haul Road

Four days of operations on the mine haul road were recorded, as can be seen from the TSP values plotted in Figure 8. These high-volume measurements, collected at 200 meters above the plant site at the southern-most switchback, were run for 0.5 to 1.5 hours under varying gusty and calm conditions. Vehicle-induced dust is clearly evident in Figure 8, although occasional measurements were lower than background trends. While the general wind direction during the day was upslope (north), the prevailing direction at the southpoint location was westerly. Downwind samplers were spotted from 10 to 18 meters east of the road edge (10 ME, 12 ME, etc.). The scatter of the TSP data values suggest that local gusts and calms can strongly affect the range of TSP values, and a single high-volume unit would not be likely to yield a realistic "average" characterization. The midrange seemed to be around 2 milligrams/cubic meters. No dust control was being used during this time, although heavy rain in early September had reduced the dust potential. The spread of observed TSP measurements for similar vehicle traffic is around 1.5 milligrams/cubic meter, and this spread appears to mask the TSP differences expected with varying traffic.

Crushing Area

Measurements in the crushing area were not emphasized since the crusher was not representative of equipment that would be used by industry, so that TSP values were not plotted. Background levels were the same as the retorted shale transfer area. Some apparent "dust concentrations" have been calculated for the crusher area and other areas and are reported in Appendix A, as determined from particle sizing collections.

PARTICULATE SIZE DISTRIBUTIONS

Particulate size distributions were calculated from the mass collections on five cascade impactor plates, plus the mass on the filter (stage 6) of the high-volume unit supporting the cascade impactor. The actual mass values, varying from total amounts of 1.3 grams to 0.03 grams are listed in Appendix A. The Sierra Instruments impactor used in this study has been designed for nominal size separations listed as follows:

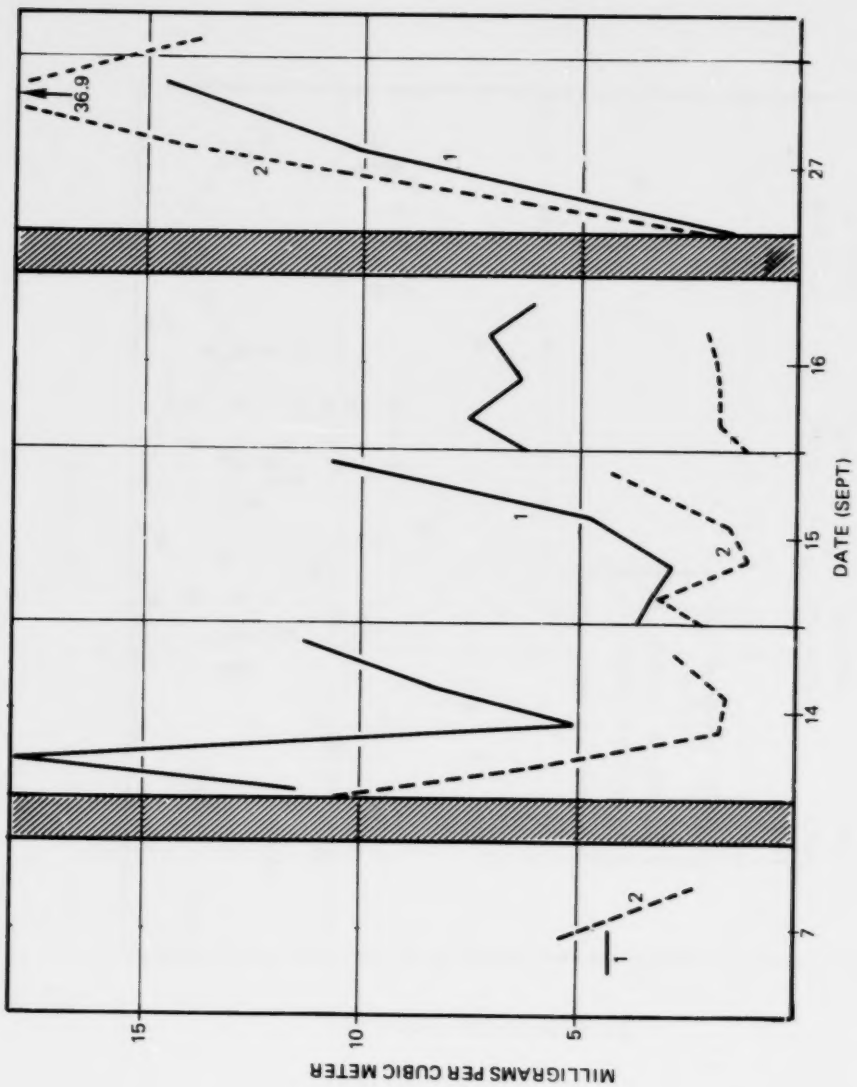

Figure 7. TSP values for mine adits 1 and 2.

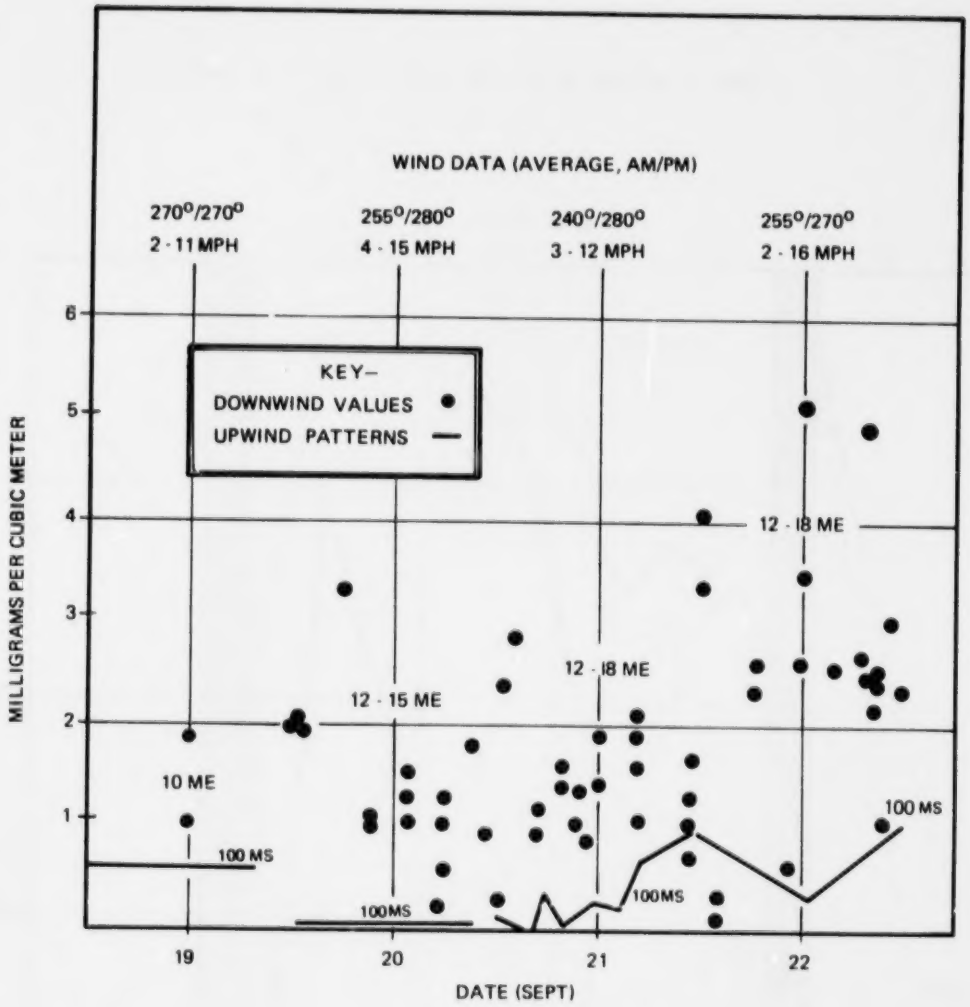

Figure 8. TSP values for haul road (South Point) location.

Stage	1	2	3	4	5	6 (filter)
Range	8μ+	8-3μ	3-1.5μ	1.5-1μ	1-0.5μ	0.5μ

The size ranges adjusted for flowrate calibration, together with weight percentages found in each of six stages, are summarized in Table 5. The inclusion of the high-volume filter as a sixth stage is a key assumption, and presumes that the manufacturer is correct in claiming that the particulate sizes reaching the high-volume filter are in the 0.5 micron (and less) class. This assumption also is implicit in the calculated equivalent mass median aerodynamic diameter, Dp = 1.4 microns.

TRW does not feel that high confidence can be assigned to this particle size data. The apparent indication of strong bimodel distributions concentrated in the 8 micron and 0.5 micron ranges is a suspect result, and could have been the consequence of inefficient particle collection at each stage. A detailed description of the Sierra Instruments cascade impactor is given in Appendix A, together with experimental collection characteristics of these types of particle sizing devices and optical scanning results of random filters from mine/haul road/crushing/retort locations. Other researchers found that high-volume collectors tend to discriminate against larger (> 10 micron) size particles, and that particle bounce-off at each impactor stage will result in underweight results in larger size ranges, and overweight results in smaller size ranges. Bounce-off errors are further substantiated by optical scan results reported in Appendix A. A measure of the uncertainty in interpreting these particulate sizing data is shown in Figure 9, where the mass median diameter of retorted shale dust is calculated to be 1.4 microns when the filter is assumed to contain only particles under 0.5 microns. The other extreme possibility shown is where the mass of particles collected on the filter is assumed to be evenly distributed among the size ranges identified with the five preceding stages and the resulting mass median diameter is calculated to be 6.5 microns. The most likely median size of all dust particles in the retorted shale handling area is probably closer to the larger estimate of 6.5 microns, since particles greater than 10 microns are not well collected. Future sampling should use an inlet cyclone ahead of the cascade impactor, to collect particles above 5 microns.

INORGANIC ANALYSES

Average elemental analyses, done for selected samples from each plant and mine area, are given in Table 6 with backup data listed in Table B-3, Appendix B. For the most part, the elemental values had good internal consistency, even though sample sizes were as small as 20 milligrams in some cases. It was found that a 2 milligram sample gave completely variant results.

Most of the elemental concentrations range within + 50% of published elemental analyses for raw oil shale. It was expected that retorted shale dust would show a depletion of the volatile elements mercury and arsenic, as well as sulfur, but there is insufficient evidence presented here to make such a claim.

TABLE 5. PARTICULATE SIZE DISTRIBUTIONS FROM CASCADE IMPACTOR AVERAGE DATA*

Location	Size range (microns)***	5 Stages + filter	5 Stages only
Haul road (average of 13 samples)	8.3 +	32.1 wt %	65 wt. %
	8.3 - 3.5	9.3	19
	3.5 - 1.7	3.6	7
	1.7 - 1.1	2.4	5
	1.1 - 0.6	2.4	4
	0.6 -	50.3	-
Mine (average of 8 samples)	9.5 +	29.5	44
	9.5 - 3.9	21.5	32
	3.9 - 2	7.6	11
	2 - 1.2	4.8	7
	1.2 - 0.7	3.7	6
	0.7 -	33.0	-
Crusher area** (average of 6 samples)	8.8 +	20.2	54
	8.8 - 3.7	4.0	11
	3.7 - 1.9	3.8	10
	1.9 - 1.2	5.0	13
	1.2 - 0.6	4.3	12
	0.6 -	62.7	-
Retorted shale transfer area (average of 9 samples)	8.3 +	37.1	69
	8.3 - 3.5	7.3	13
	3.5 - 1.8	3.0	6
	1.8 - 1.1	3.5	7
	1.1 - 0.6	2.8	5
	0.6 -	46.3	-

*Optical sizing of particulates indicates that cascade impactors have a significant bounce error - see Appendix A, Table A-6
**Crusher is not typical of equipment that likely would be used by industry
***Size ranges determined by flowrate calibration curves supplied by manufacturer

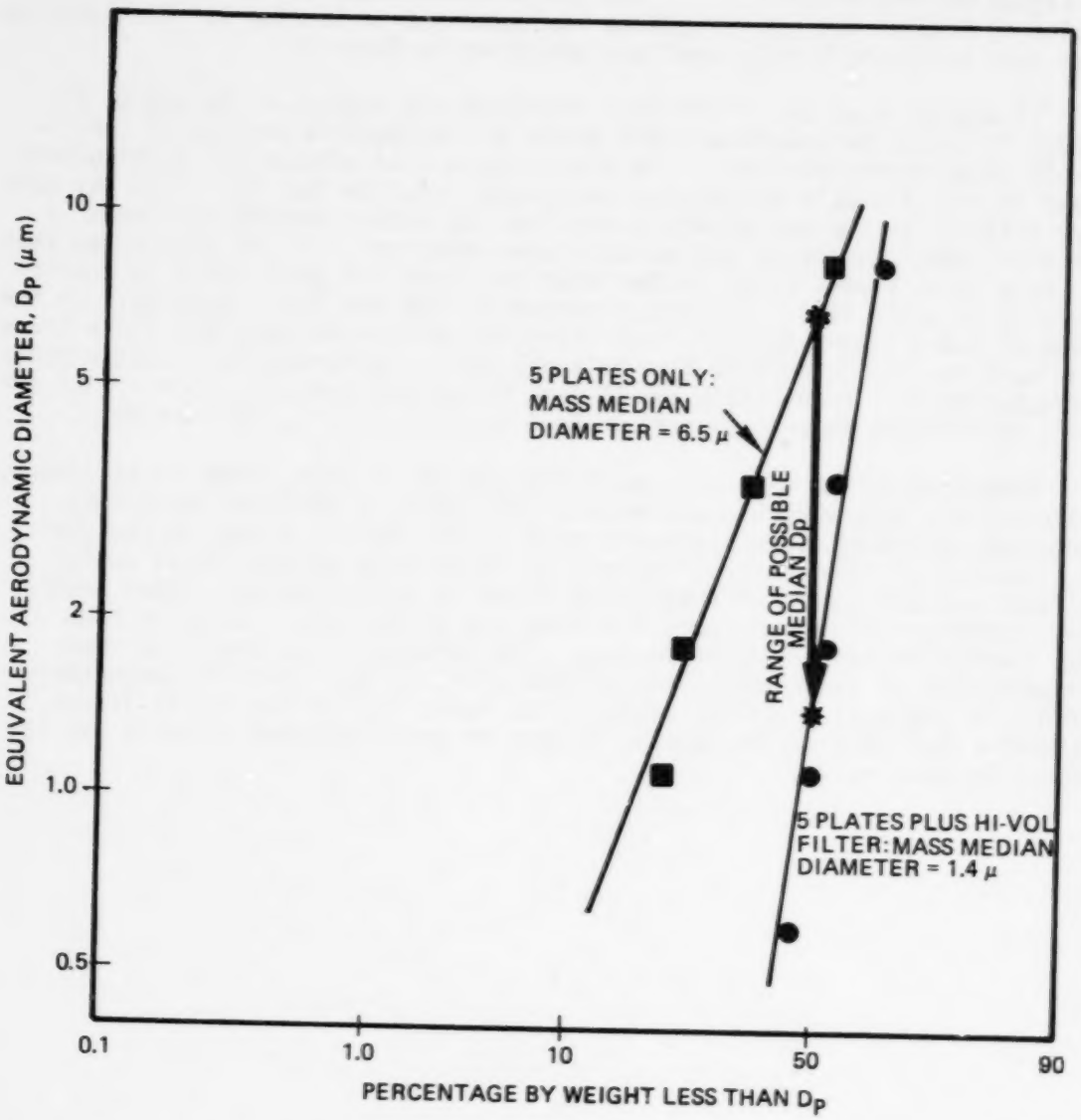

Figure 9. Equivalent aerodynamic diameter of retorted shale dusts.

ORGANIC ANALYSES

Selected samples were extracted for organics, and the extracts separated by liquid chromatograph (L.C.). The analysis rationale and generic classification of each of the L.C. fractions was described in Section 3. The quantitative results of these fractionations are given in Table 7.

It appears that the predominant fractions are numbers 1, 5, and 6, although it should be understood that there is considerable overlap of constituents in adjacent fractions. The mine-related dust samples are particularly heavy in the aliphatic hydrocarbon-containing fraction (No. 1). This may have been affected by the use of ANFO explosives and diesel powered equipment in the mine, both sources of hydrocarbon-laden emissions. It was also noted that all mine samples were black, rather than the light tan color which is characteristic of shale dust. Organic extractables from raw shale dusts were in the range of 1.5-4 weight percent, indicating the well-known fact that shale fines are lower in organic content than bulk oil shale. Retorted shale dust organic extractables were predictably low (0.3 to 0.5 weight percent); much of the organic constituent removal appears to have occurred in L.C. fraction No. 1.

Elemental sulfur will show up in fraction No. 1 also, since it is solvent extractable. This effect would be most noticeable in retorted shale dust, since the retorting process converts much of the organic sulfur in raw shale to elemental or free sulfur. There is no correlation between total sulfur analyses and the amount of free sulfur found in shale samples. Other tentative characterizations of these fractions are in Appendix C based on some very limited infrared absorbence data. The infrared scans showed up some contamination of the filters from silicon oils, so that specific characterization of the L.C. fractions could not be done. In the future, it is recommended that high-volume sampler filters be decontaminated prior to use by solvent extraction.

TABLE 6. AVERAGE ELEMENTAL COMPOSITIONS OF FUGITIVE DUSTS (UNITS IN PPM)

	Crusher area	Retorted shale transfer area	Mine adit	Haul road	Raw shale screening room baghouse area	Upwind areas
Cd	ND	5	2	2	6	2
Ca	28,655	105,617	75,025	82,300	62,533	102,650
Cr	15	31	13	29	54	72
Cu	40	71	145	133	53	231
Fe	19,150	17,783	13,325	22,933	22,767	20,270
Mg	20,450	28,735	27,725	50,567	39,167	34,170
Na	13,040	22,368	32,155	20,333	28,767	15,550
Ni	12	30	19	43	39	321
Pb	17	55	68	96	64	195
V	24	131	43	57	228	38
Zn	161	179	150	200	165	420
Mn	135	295	315	503	---	272
Al	11,188	15,634	12,761	27,073	41,700	30,528
As	3.8	14.9	7.8	16.3	16.6	4.5
Se	11	11.7	4.4	34.8	35.3	14.8
Si	119,145	41,112	83,000	299,000	50,367	104,850
S	243	5,271	13,450	2,950	6,400	4,525
F	745	1,291	1,925	10,800	975	6,923
Hg	11.5	0.2	0.1	0.9	0.3	*

*samples too small

TABLE 7. AVERAGE ORGANIC COMPOSITIONS OF DUST SAMPLES

	Wt % Organic Solubles	Wt % per fraction								
		1	2	3	4	5	6	7	8	9
Average of Mine Related Samples	3.88	59.5	3.9	5.1	2.3	18.9	4.7	1.2	1.5	2.8
Average of Raw Shale Crushing and Handling Areas	1.19	36.5	7.4	5.8	2.1	25.1	17.3	1.8	2.5	3.0
Average of Retorted Shale Handling Areas	0.52	38.7	4.9	5.1	3.6	27.1	12.4	2.4	2.9	2.8

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APPENDIX A

PARTICULATE COLLECTION EQUIPMENT AND PERFORMANCE

TSP DATA COLLECTION AND REDUCTION

The high-volume collectors (specified in Table A-7) were placed at downwind locations for the various fugitive dust sources and also at upwind locations for background measurements. Samplers at the mine were actually located about 10 meters inside the two mine adits, so wind was not a factor with these positions. Equipment locations and prevailing wind directions are generally indicated in Figure A-1.

High-volume sampling at the haul road was initiated just prior to the approach of a vehicle, and continued for 0.5-1 hours. In this time, two to eight more vehicles would pass the sampling area, including pickup trucks as well as dump trucks. There was no attempt made to collect a sample during the approximate passage time of a single truck, since the measurement would have been below the detection limit. The sampling location was beside a short (about 30 to 40 meters) section of haul road between two switchbacks. The road traversed the prevailing wind direction. The two downwind samplers were separated about 15 meters along the road; a haul vehicle moving at an estimated 9 meters/sec (20 miles/hour) would have taken 1.5 seconds to pass.

The chronological listing of all samples collected for total suspended particulate (TSP) determinations is presented in Table A-1. In addition, apparent TSP calculations derived from particulate sizing tests are shown in Table A-2 to backup the observation that small sampling volumes (15-30 cubic meters) may yield quite different TSP values, and they should not be taken as an adequate characterization of dust concentrations. The raw data of average air flow rate through the collector was converted to cubic meters (@ 1 atmosphere and 20° C) by using the indicated sampling time, pressure corrections and temperature corrections. The location code for the high-volume samplers is as follows:

RDW - retorted shale transfer, downwind
RUW - retorted shale transfer, upwind
CDW - crushing area, downwind
CUW - crushing area, upwind
HRDW - haul road, downwind
HRUW - haul road, upwind
MA 1 - mine adit No. 1
MA 2 - mine adit No. 2

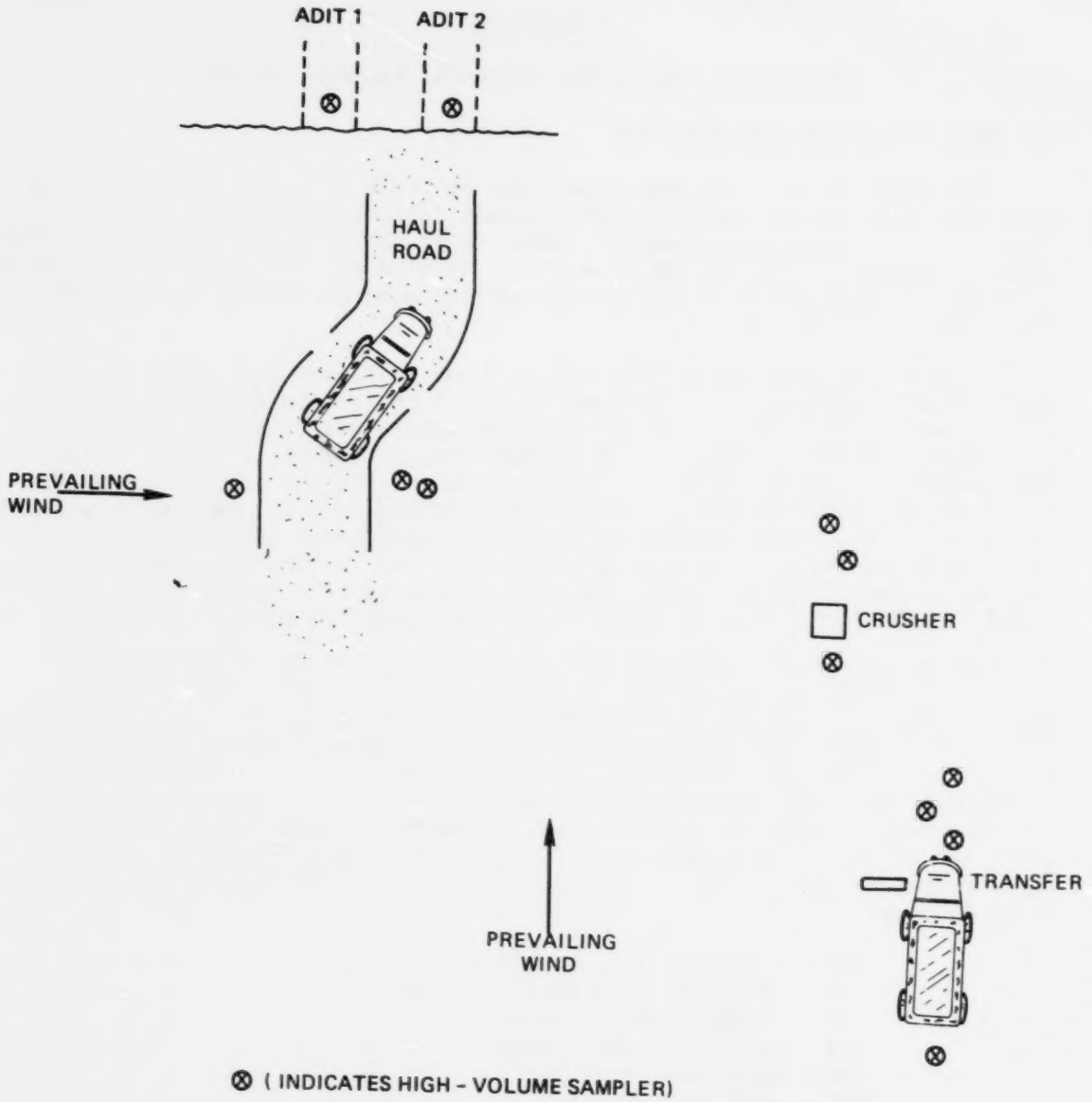

Figure A-1. Placement of particulate matter collection equipment.

PARTICULATE SIZE ANALYSIS

Equipment

Size fractionation of suspended particulates was accomplished with a high-volume cascade impactor (Sierra Instruments Model 235), which mounted directly on top of the high-volume samplers used for total particulate collection. The impactor (Figure A-2) design consists of a series of five slotted plates with decreasing slot widths from the first impaction stage to the last stage. Particles collect on a lightweight fiberglass substrate at each stage, and the remaining particles that do not impact on any of the five stages are collected by the back-up filter in the high-volume sampler.

At 40 cubic feet/minute[1] nominal flowrate, the expected particle size cut-off diameters at 50 percent collection efficiency for spherical particles with unity mass density is specified as follows:

Stage	1	2	3	4	5
50% cut-off (microns)	7.2	3.0	1.5	0.95	0.49

Performance Analysis

The mass distribution on each stage of the cascade impactor is recorded for each particulate sizing test in Table A-3; Stage 6 is the backup filter. These values were converted to weight percent distribution in Table A-4, and the expected lower limit particle size cutoffs were determined (Table A-5) from the manufacturer's flowrate calibrations. The efficiency of particle collection by high-volume samplers is known to be sharply reduced for particles greater than 10 micron diameter, and also that sampler orientation to wind direction is critical.[2] The heavier particles in fugitive dusts at the various locations were probably not included in the reported sample catch. Once in side the high-volume sampler, particle bounce errors can lead to further distortion of the size distribution observations.[3] Around 20-25 percent of 1-2 micron particles can get through to a backup filter.[4] If the collection efficiency at each impactor stage were known as a function of particle size, numerical evaluation and correction of errors could be accomplished.[5]

An examination of the data averages for particle size distributions (Table 5) shows an apparent bimodal distribution, with 30 to 50 percent of the total sample catch appearing on the backup filter. If the mass of particulate on the backup filter is treated as though it really is less than 0.6 microns in diameter, calculated mass median diameters (e.g., Figure 9) will be less than typical urban suspended particulates.[6] This conclusion is clearly invalid, and an optical scanning analysis of randomly selected backup filters was conducted to provide a limited estimate of the extent of particle sizing inefficiencies. These results are given in Table A-6, together with an estimate of the corrections in observed mass distributions when the particles counted on the filters are assumed to be spherical and unity density.

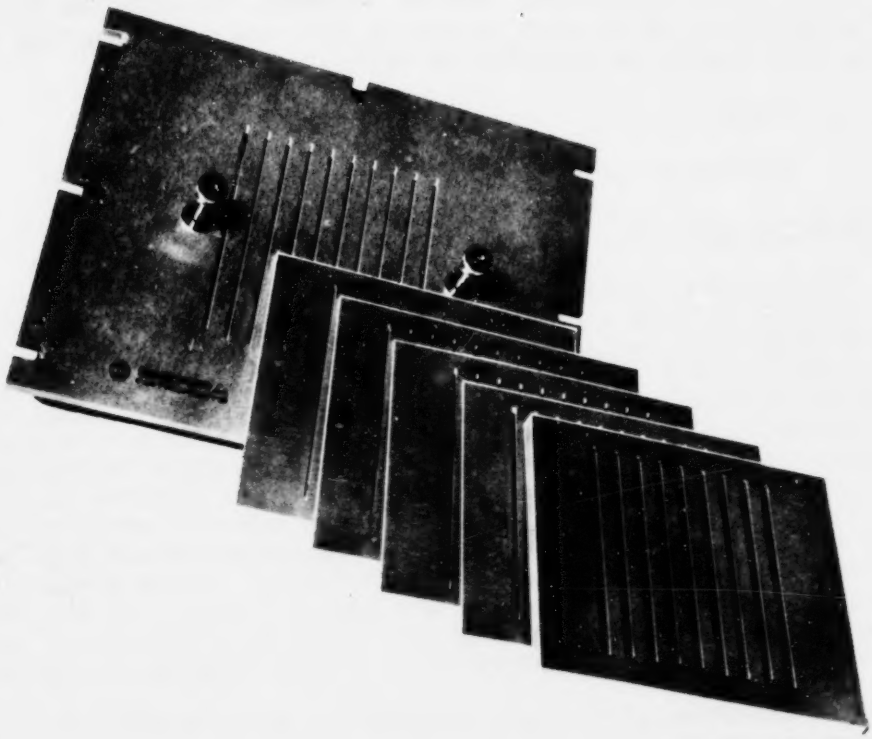

Figure A-2. Cascade impactor plates.

TRW believes that the trend of particle size distributions on the selected high-volume filters summarized in Table A-6 provides convincing evidence that the cascade impactor separation was subject to a great deal of particle bounce error. Particles in the 3-to-8 microns range dominate the weight percentage on these filters, and the range that the filters are intended to catch (0-1 microns) represent a negligible weight percentage.

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6. M.G. Wadley, et.al., "Size Distribution Measurements of Particulate Matter in Los Angeles and Anaheim using High-Volume Anderson Samplers", J. APCA, 28:4 (1978).

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES

Date	Location	Hi-vol no.	Filter no.	Average T °F	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters @ 20°C (mg)	mg/m³
9/03/77	RDW	11	1122755	72	24.09	43.5	199	.8051	.9962	6943	4519.	194.4	23.2
9/04/77	RDW	11	1122798	70	24.12	36	1140	.8061	1.0	33082	10126.	926.3	10.93
9/04/77	RUW	8	1122753	70	24.12	60	172	.8061	1.0	8319	167.1	232.9	0.717
9/04/77	RDW	7	1122799	70	24.12	55	61	.8061	1.0	2704	289.4	75.7	3.82
9/04/77	RDW	11	1122752	70	24.12	53.5	61	.8061	1.0	2631	634.4	73.7	8.61
9/04/77	CDW		1122754	70	23.92	51	391	.7995	1.0	15943	1847.6	446.4	4.14
9/05/77	RDW	11	1122794	73	24.11	53	60	.8058	.9944	2548	523.9	71.3	7.35
9/5-9/6/77	RDW	7A	1125597	73	24.11	45	1230	.8058	.9944	44351	11901.4	1241.8	9.58
9/05/77	RUW	8	1122796	73	24.11	60	192	.8058	.9944	9231		258.5	
9/05/77	RDW	7	1122795	73	24.11	35	60	.8058	.9944	1683	331.5	47.1	7.04
9/05/77	RDW	11	1122789	73	24.11	52.5	60	.8058	.9944	2524	484.3	70.7	6.85
9/05/77	RDW	7	1122790	73	24.11	37.5	60	.8058	.9944	1803	260.8	50.5	5.16
9/05/77	RUW	8	1122797	73	24.11	70	150	.8058	.9944	8414	116.5	235.6	0.494
9/06/77	RUW	8	1122782	74	24.10	67.5	135	.8055	.9925	7285	213.4	204.0	1.05
9/06/77	RDW	7	1122778	74	24.10	37	90	.8055	.9925	2662	644.2	74.5	8.65
9/06/77	RDW	11	1122774	74	24.10	55	90	.8055	.9925	3957	1359.2	110.8	12.27
9/06/77	RUW	8	1122781	74	24.10	70	120	.8055	.9925	6715	132.9	188.0	0.706
9/06/77	RDW	11	1122783	74	24.10	59.5	125	.8055	.9925	5946	423.4	166.5	2.54
9/06/77	RDW	7	1122780	74	24.10	29	60	.8055	.9925	1391	242.4	38.9	6.23
9/06/77	RDW	7A	1122784	74	24.10	45	300	.8055	.9925	10793	17481.2	302.2	
9/06/77	RDW	7	1122779	74	24.10	39	60	.8055	.9925	1871	369.6	52.4	7.05
9/06/77	RUW	8	1122787	74	24.10	70	105	.8055	.9925	5876	151.2	164.5	0.919
9/07/77	MA1	4A	1122762	75	21.58	47	60	.7213	.9907	2015	240.2	56.4	4.26
9/07/77	MA2	5	1122761	75	21.58	30	60	.7213	.9907	1286		36.0	
9/07/77	MA2	5	1122750	75	21.58	40	60	.7213	.9907	1715	261.3	48.0	5.44
9/07/77	MA1	4A	1122760	75	21.58	50	60	.7213	.9907	2144	258.3	60.0	4.31
9/07/77	MA2	5	1122748	75	21.60	40	60	.7219	.9907	1716	112.2	48.0	2.34
9/07/77	MA1	4A	1122749	75	21.60	49	60	.7219	.9907	2103		58.9	
9/7-9/77	RDW	7A	1122751	75	24.13	45	1367	.8065	.9907	49150		1376.2	
9/08/77	RDW	11	1122764	75	24.06	60	90	.8041	.9907	4302	325.5	120.5	2.70
9/08/77	RUW	8	1122763	75	24.06	70	115	.8041	.9907	6413	168.9	179.6	.940
9/08/77	RDW	7	1122765	75	24.06	30	90	.8041	.9907	2151	190.7	60.2	2.17
9/08/77	RDW	7	1122783	75	24.06	45	80	.8041	.9907		317.9		
9/08/77	RUW	8	1122744	75	24.06	70	110	.8041	.9907	6134	110.6	171.8	.644
9/08/77	RDW	11	1122737	75	24.06	58	60	.8041	.9907	2772	575.9	77.6	7.42
9/08/77	CUW	9	1122771	75	24.06	70	134	.8041	.9907	7472	207.0	209.2	.989

(continued)

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES (continued)

Date	Location	Hi-vol no.	Filter no.	Average $^{o}_{T}F$	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters (mg) @ 20°C	mg/m^3
9/08/77	CDW	10	1122779	75	24.06	65	56	.8041	.9907	2900	241.2	81.2	2.97
9/08/77	CDW	6	1122772	75	24.06	50	56	.8041	.9907	2231	418.0	62.5	6.66
9/08/77	RUW	8	1122740	75	24.06	74	120	.8041	.9907	7074	160.0	198.1	.808
9/08/77	RDW	7	1122743	75	24.06	32	90	.8041	.9907	2294	361.0	64.2	5.62
9/08/77	RDW	11	1122741	75	24.06	57.5	90	.8041	.9907	4122	749.6	115.4	6.50
9/08/77	RUW	8	1122739	75	24.06	70	105	.8041	.9907	5855	157.4	163.9	.960
9/08/77	RDW	11	1122735	75	24.06	58	90	.8041	.9907	4158	690.6	116.4	5.93
9/08/77	RDW	7	1122738	75	24.06	45	90	.8041	.9907	3226		90.3	
9/08/77	RDW	7A	1122742	75	24.06	75	1455	.8041	.9907	86929	12289.4	2434.0	5.05
9/09/77	CDW	10	1122769	71	24.03	70	87	.8031	.9981	4882	173.3	136.7	1.27
9/09/77	CDW	6	1122770	71	23.83	50	35	.7965	.9981	1391	256.3	38.9	6.59
9/09/77	CUW	9	1122768	71	23.83	72.5	135	.7965	.9981	7781	222.9	217.9	1.02
9/09/77	CUW	9	1122766	71	23.83	70	35	.7965	.9981	1948	143.2	54.5	2.63
9/08/77	RDW	7	1122736	75	24.06	36.5	90	.8041	.9907	2617	381.0	73.3	5.20
9/10/77	CUW	9	1122732	71	23.83	75	155	.7965	.9981	9242	182.3	258.8	
9/09/77	CDW	10	1122734	71	23.83	70	20	.7965	.9981	1113	248.4	31.2	7.96
9/09/77	CDW	6	1122767	71	23.83	55	20	.7965	.9981	874	137.1	24.5	5.60
9/10/77	CDW	6	1122730	73	24.06	50	60	.8041	.9944	2399	354.0	67.1	5.28
9/10/77	CDW	10	1122731	6	6	70	60	.8041		3358	327.0	94.0	3.48
9/14/77	MA2	5	1122790	62	21.52	30	29	.7193	1.015	635	189.9	17.8	10.67
9/14/77	MA1	4A	1122793	62	21.52	40	37	.7193	1.015	1081	313.4	30.3	10.34
9/14/77	MA2	5	1125501	67	21.52	37.5	57	.7193	1.015	1561	263.3	43.7	6.03
9/14/77	MA1	4A	1125532	62	21.52	42.5	57	.7193	1.015	1769	891.5	49.5	18.01
9/14/77	MA2	5	1122776	62	21.52	42.5	60	.7193	1.015	1862	91.3	52.1	1.75
9/14/77	MA1	4A	1125531	62	21.52	45	59	.7193	1.015	1938	277.6	54.3	5.11
9/14/77	MA2	5	1125594	62	21.52	45	61	.7193	1.015	2004	95.5	56.1	1.70
9/14/77	MA1	4A	1125595	62	21.52	45	59	.7193	1.015	1938	457.9	54.3	8.43
9/14/77	MA2	5	1122786	62	21.52	45	61	.7193	1.015	2004	163.5	56.1	2.91
9/14/77	MA1	4A	1122185	62	21.52	45	59	.7193	1.015	1971	628.0	55.2	11.38
9/15/77	MA2	4A	1122748	59	21.52	50.5	63	.7193	1.021	2333	145.1	65.3	2.22
9/15/77	MA1	8	1122758	59	21.52	45	59	.7193	1.021	1947	201.5	54.5	3.70
9/15/77	MA2	4A	1125573	59	21.52	43	58	.7193	1.021	1829	163.3	51.2	3.19
9/15/77	MA1	8	1122791	59	21.52	425	60	.7193	1.021	1870	180.8	452.4	3.45

(continued)

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES (continued)

Date	Location	Hi-vol no.	Filter no.	Average T °F	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters (mg) @ 20°C	mg/m^3
9/15/77	MA2	4A	1125589	59	21.40	52	31	.7152	1.021	1177	39.3	33.0	1.191
9/15/77	MA1	8	1125590	59	21.40	47.5	29	.7152	1.021	1006	81.9	28.2	2.90
9/15/77	MA2	4A	1122728	59	21.40	50	63	.7152	1.021	2300	103.4	64.4	1.606
9/15/77	MA1	8	1125591	59	21.40	42.5	66	.7152	1.021	2048	275.0	57.3	4.80
9/15/77	MA2	4A	1125592	59	21.40	50	54	.7152	1.021	1972	238.5	55.2	4.32
9/15/77	MA1	8	1125600	59	21.40	40	44	.7152	1.021	1285	386.1	36.0	10.73
9/16/77	MA1	8	1125585	62	21.40	42.5	62	.7152	1.015	1913	333.2	53.6	6.22
9/16/77	MA2	4A	1125586	62	21.40	50	58	.7152	1.015	2105	68.3	58.9	1.160
9/16/77	MA1	8	1125587	62	21.40	42.5	59	.7152	1.015	1820	389.5	51.0	7.64
9/16/77	MA2	4A	1125508	62	21.40	47.5	57	.7152	1.015	1965	100.3	55.0	1.82
9/16/77	MA1	8	1125509	62	21.40	42.5	60	.7152	1.015	1851	333.4	51.8	6.44
9/16/77	MA2	4A	1125510	62	21.40	47.5	59	.7152	1.015	2034	104.5	57.0	1.83
9/16/77	MA1	8	1125511	62	21.40	42.5	47	.7152	1.015	1450	287.4	40.6	7.08
9/16/77	MA2	4A	1125512	62	21.40	47.5	55	.7152	1.015	1896	102.4	53.1	1.93
9/16/77	MA1	8	1125514	62	21.40	42.5	60	.7152	1.015	1851	314.3	51.8	6.07
9/16/77	MA2	4A	1125513	62	21.40	47.5	56	.7152	1.015	1931	116.5	54.1	2.15
9/19/77	HRUW	1	1125518	62	23.21	55	76	.7757	1.015	3291	58.4	92.1	0.634
9/19/77	HRDW	9	1125515	62	23.21	70	74	.7757	1.015	4078	176.0	114.2	15.6
9/19/77	HRDW	10	1125516	62	23.21	72.5	74	.7757	1.015	4224	135.9	118.3	1.15
9/19/77	HRDW	6	1125521	62	23.21	46.5	72	.7757	1.015	2636	72.9	73.8	0.988
9/19/77	HRUW	1	1125519	62	23.21	52.5	91	.7757	1.015	3761	67.8	105.3	0.644
9/19/77	HRDW	10	1125583	62	23.21	65	87	.7757	1.015	4452	125.0	124.7	1.00
9/19/77	HRDW	9	1125522	62	23.21	62.5	87	.7757	1.015	4281	215.4	119.9	1.80
9/19/77	HRDW	9	1125544	62	23.21	50	53	.7757	1.015	2086	106.9	58.4	1.83
9/20/77	HRDW	10	125527	64	23.16	45	61	.7741	1.011	2148	124.3	60.1	2.07
9/20/77	HRDW	6	125528	64	23.16	40	61	.7741	1.011	1910	110.1	53.5	2.06
9/20/77	HRDW	9	125526	64	23.16	42.5	61	.7741	1.011	2029	51.3	56.8	0.903
9/20/77	HRUW	11	15	64	23.16	48	67	.7741	1.011	2517		70.5	
9/20/77	HRUW	1	14	64	23.16	48	73	.7741	1.011	2742		76.8	
9/20/77	HRDW	5	16	64	23.16	37.5	60	.7741	1.011	1761	162.3	49.3	3.29
9/20/77	HRDW	5	13	64	23.16	41	99	.7741	1.011	3177	98.3	89.0	1.104
9/20/77	HRDW	7	12	64	23.16	41	94	.7741	1.011	3016	88.3	84.4	1.05
9/20/77	HRUW	11	9	64	23.16	51	102	.7741	1.011	4071		114.0	
9/20/77	HRUW	1	11	64	23.16	45	101	.7741	1.011	3557		99.6	

(continued)

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES (continued)

Date	Location	Hi-vol no.	Filter no.	Average T °F	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters (mg) @ 20°C	mg/m^3
9/20/77	HRDW	9	1125508	64	23.16	45	89	.7741	1.011	3134	113.0	87.8	1.29
9/20/77	HRDW	6	1125507	64	23.16	40	87	.7741	1.011	2723	79.6	76.2	1.04
9/20/77	HRDW	10	1125505	64	23.16	45	89	.7741	1.011	3134	135.9	87.8	1.55
9/20/77	HRDW	6	34	64	23.16	42.5	99	.7741	1.011	3293	20.3	92.2	0.220
9/20/77	HRDW	9	36	64	23.16	40	99	.7741	1.011	3099	91.3	86.8	1.05
9/20/77	HRDW	10	35	64	23.16	40	99	.7741	1.011	3099	47.0	86.8	0.541
9/20/77	HRDW	7	33	64	23.16	46	111	.7741	1.011	3996	135.3	111.9	1.21
9/20/77	HRUW	11	29	64	23.16	50	85	.7741	1.011	3326		93.1	
9/20/77	HRUW	1	30	64	23.16	48	77	.7741	1.011	2892		81.0	
9/20/77	HRDW	5	10	64	23.16	41	42	.7741	1.011	1348	71.0	37.7	1.88
9/20/77	HRDW	5	31	64	23.16	42.5	63	.7741	1.011	2095	56.0	58.7	0.954
9/21/77	HRUW	1	1125554	61	23.21	50	93	.7757	1.017	3668	12.6	102.7	0.123
9/21/77	HRDW	9	26	61	23.21	45	65	.7757	1.017	1515	21.2	64.6	0.328
9/21/77	HRDW	10	32	61	23.21	47.5	65	.7757	1.017	2436	2.4	68.2	0.035
9/21/77	HRDW	5	1125555	61	23.21	49	61	.7757	1.017	2358	159.2	66.0	2.41
9/21/77	HRUW	11	25	61	23.21	50	40	.7757	1.017	1578		44.2	
9/21/77	HRDW	7	1125556	61	23.21	57.5	59	.7757	1.017	2676	215.1	74.9	2.87
9/21/77	HRUW	1	1125567	61	23.21	52	54	.7757	1.017	2215	28.1	62.0	0.453
9/21/77	HRDW	7	112553	61	23.21	60	104	.7757	1.017	4923	127.0	137.8	0.922
9/21/77	HRDW	5	1125580	61	23.21	50	99	.7757	1.017	3905	135.3	109.3	1.24
9/21/77	HRUW	11	1125504	61	23.21	52	148	.7757	1.017	6071	16.1	170.0	0.095
9/21/77	HRDW	9	1125578	61	23.21	50	68	.7757	1.017	2682	104.2	75.1	1.39
9/21/77	HRDW	6	1125503	61	23.21	47.5	68	.7757	1.017	2548	110.8	71.3	1.55
9/21/77	HRDW	10	1125579	61	23.21	50	68	.7757	1.017	2682	77.9	75.1	1.04
9/21/77	HRDW	6	1125549	61	23.21	30	94	.7757	1.017	2225	83.6	62.3	1.34
9/21/77	HRDW	9	1125581	61	23.21	50	94	.7757	1.017	3708		103.8	
9/21/77	HRDW	10	1125550	61	23.21	50	94	.7757	1.017	3708	93.1	103.8	0.897
9/21/77	HRUW	1	1125543	61	23.21	50	114	.7757	1.017	4497	34.3	125.9	0.272
9/21/77	HRUW	11	1125552	61	23.21	52	114	.7757	1.017	4677	27.1	131.0	0.207
9/21/77	HRDW	5	1125548	61	23.21	47.5	114	.7757	1.017	4277	232.1	119.6	1.94
9/21/77	HRDW	7	1125547	61	23.21	52.5	114	.7757	1.017	4722	189.4	132.2	1.43
9/21/77	HRUW	11	1125537	61	23.21	50	68	.7757	1.017	2682	16.9	75.1	0.225
9/21/77	HRUW	1	1125538	61	23.21	45	68	.7757	1.017	2414	49.2	67.6	0.728
9/21/77	HRDW	6	1125551	61	23.21	45	70	.7757	1.017	2485	151.8	69.6	2.18
9/21/77	HRDW	10	1125541	61	23.21	47.5	70	.7757	1.017	2623	136.8	73.4	1.86
9/21/77	HRDW	9	1125542	61	23.21	50	70	.7757	1.017	2761	126.3	77.3	1.63
9/21/77	HRDW	6	1125535	61	23.21	42.5	44	.7757	1.017	1475	46.5	41.3	1.13

(continued)

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES (continued)

Date	Location	Hi-vol no.	Filter no.	Average T °F	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters (mg) @ 20°C	mg/m^3
9/21/77	HRDW	10	1125534	61	23.21	42.5	44	.7757	1.017	1475	43.2	41.3	1.05
9/21/77	HRDW	9	1125536	61	23.21	45	44	.7757	1.017	1562	31.4	43.7	0.719
9/21/77	HRDW	5	1125539	61	23.21	50	68	.7757	1.017	2682	95.1	75.1	1.27
9/21/77	HRDW	7	1125540	61	23.21	42.5	68	.7757	1.017	2775	131.9	77.7	1.70
9/22/77	HRUW	11	1125560	61	23.12	42.5	38	.7727	1.017	1269	62.9	35.5	1.77
9/22/77	HRUW	1	1125561	61	23.12	48	65	.7727	1.017	2452	66.1	68.7	0.962
9/22/77	HRDW	5	1125563	61	23.12	53	71	.7727	1.017	2957	335.4	82.8	4.05
9/22/77	HRDW	7	1125562	61	23.12	53.5	71	.7727	1.017	2985	273.8	83.6	3.28
9/22/77	HRDW	10	49	61	23.12	47.5	62	.7727	1.017	2314	8.1	64.8	0.125
9/22/77	HRDW	9	48	61	23.12	40	62	.7727	1.017	1949	16.8	54.6	0.308
9/22/77	HRDW	5	40	61	23.12	38	75	.7727	1.017	2240	145.2	62.7	2.32
9/22/77	HRDW	10	101	61	23.12	40	67	.7727	1.017	2106	155.5	59.0	2.63
9/22/77	HRDW	6	22	61	23.12	40	67	.7727	1.017	2106	34.1	59.0	0.578
9/22/77	HRDW	9	100	61	23.12	40	67	.7727	1.017	2106	157.3	59.0	2.67
9/22/77	HRUW	1	1122713	61	23.12	54	37	.7727	1.017	1570	20.9	44.0	0.475
9/22/77	HRDW	7	1122714	61	23.12	52	37	.7727	1.017	1512	149.1	42.3	3.52
9/22/77	HRDW	5	1122715	61	23.12	45	37	.7727	1.017	1308	188.4	36.6	5.15
9/22/77	HRUW	11	1122711	61	23.12	52	37	.7727	1.017	1512	21.6	42.3	0.511
9/22/77	HRDW	9	1125568	61	23.12	52	38	.7727	1.017	1552	110.4	43.2	2.55
9/22/77	HRUW	1	1122717	61	23.12	50	76	.7727	1.017	2986	32.5	83.6	0.389
9/22/77	HRUW	11	1122716	61	23.12	51	76	.7727	1.017	3046	65.7	85.3	0.770
9/22/77	HRDW	7	1122718	61	23.12	54.5	76	.7727	1.017	3255	249.1	91.1	2.73
9/22/77	HRDW	5	1125560	61	23.12	45	76	.7727	1.017	2687	373.6	75.2	4.97
9/22/77	HRDW	6	96	61	23.12	42.5	77	.7727	1.017	2571	168.9	72.0	2.35
9/22/77	HRDW	10	98	61	23.12	40	77	.7727	1.017	2420	148.4	67.8	2.19
9/22/77	HRDW	9	97	61	23.12	40	77	.7727	1.017	2420	154.9	67.8	2.28
9/22/77	HRDW	9	1125565	61	23.12	45	46	.7727	1.017	1627	51.4	45.7	1.13

(continued)

TABLE A-1. TOTAL SUSPENDED PARTICULATE VALUES (continued)

Date	Location	Hi-vol no.	Filter no.	Average T °F	Average barometric pressure (MG)	Average flowrate, ACFM	Time, minutes	PA/PS pressure correction	TS/TA temperature correction	Standard cubic feet	Milligrams sample (mg)	Cubic meters (mg) @ 20°C	mg/m³
9/24-9/27	MA2	4A	1122725	61	21.38	23.5	4725	.7146	1.017	80696	1908.4	2259.5	1.48
9/22/77	HRDW	10	1125533	61	23.12	45	46	.7727	1.017	1627	67.5	45.6	2.51
9/22/77	HRDW	5	1122721	61	23.12	44.5	50	.7727	1.017	1748	147.1	48.9	3.01
9/22/77	HRUW	1	1125558	61	23.12	50	41	.7727	1.017	1611	76.4	45.1	1.69
9/22/77	HRUW	11	1122719	61	23.12	52	41	.7727	1.017	1675	38.1	46.9	0.812
9/22/77	HRUW	10	1125530	61	23.12	50	38	.7727	1.017	1493	76.1	41.8	1.82
9/22/77	HRUW	1	37	61	23.12	48	63	.7727	1.017	2376		66.5	
9/22/77	HRUW	11	38	61	23.12	52	63	.7727	1.017	2574		72.1	
9/22/77	HRDW	7	39	61	23.12	40.5	75	.7727	1.017	2387	152.4	66.8	2.28
9/23-24/77	MA1	8	90	55	21.38	23	1368	.7146	1.029	23135	135.1	647.8	0.209
9/23-24/77	MA2	12	42	55	21.38	20	1367	.7146	1.029	20103	170.9	562.9	0.304
9/23-24/77	MA2	4A	43	55	21.38	29	1370	.7146	1.029	29213	281.6	818.0	0.344
9/24/77	CUW	1	92	57	23.87	55	80	.7978	1.025	3598	85.0	72.7	1.17
9/26/77	RDW	7	82	61	23.92	38	32	.7995	1.017	989	1018.7	27.7	36.8
9/26/77	RDW	5	81	61	23.92	47	32	.7995	1.017	1223	620.7	34.2	18.15
9/24-27/77	MA1	8	1122720	61	21.40	26	4715	.7152	1.017	89167	3573.9	2496.7	1.43
9/24-27/77	MA1	12	112557	61	21.40	20	4715	.7152	1.017	68590	3589.9	1920.5	1.87
9/26/77	RDW	7	94	61	23.92	37.5	39	.7995	1.017	1189	542.5	33.3	16.3
9/26/77	RDW	7	80	61	23.92	30	51	.7995	1.017	1244	94.7	34.8	2.72
9/26/77	RDW	5	79	61	23.92	42.5	45	.7995	1.017	1555	548.2	43.5	12.60
9/26/77	RDW	9	84	61	23.92	28	55	.7995	1.017	1252	58.9	35.1	1.68
9/26/77	RUW	9	85	61	23.92	27	80	.7995	1.017	1756	98.4	49.2	2.0
9/26/77	RUW	9	05	61	23.92	29	87	.7995	1.017	2051		57.4	
9/26/77	RUW	9	04	61	23.92	30	121	.7995	1.017	2952	43.9	79.9	0.549
9/27/77	RDW	5	73	61	23.92	46	13	.7995	1.017	486	351.9	13.6	25.88
9/27/77	RUW	9	91	61	23.92	26.5	36	.7995	1.017	776	132.4	21.7	6.10
9/27/77	RDW	5	77	61	23.92	42.5	46	.7995	1.017	1590	520.9	44.5	11.71
9/27/77	RDW	7	78	61	23.92	36.5	54	.7995	1.017	1603	1316.4	44.9	29.32
9/27/77	RDW	6	70	61	23.92	46	34	.7995	1.017	1272	659.6	35.6	18.53
9/27/77	RDW	5	69	61	23.92	43	38	.7995	1.017	1329	412.4	37.2	11.09
9/27/77	MA1	8	41	61	21.40	25	162	.7152	1.017	2946	125.4	82.5	1.52
9/27/77	MA2	4A	17	61	23.92	25.5	165	.7152	1.017	3061	142.3	85.7	1.66
9/27/77	MA1	14	71	61	21.40	17.5	100	.7152	1.017	1273	78.4	35.6	2.20
9/27/77	MA2	4A	19	61	21.40	37.5	16	.7152	1.017	436	173.7	12.2	14.24
9/27/77	MA1	8	18	61	21.40	41	29	.7152	1.017	865	245.2	24.2	10.13
9/27/77	MA1	14	23	61	21.40	25.5	29	.7152	1.017	538	35.8	15.1	2.37
9/27/77	MA1	8	20	61	21.40	39	55	.7152	1.017	1560	639.0	43.7	14.62
9/27/77	MA2	4A	67	61	21.40	31	58	.7152	1.017	1308	1324.6	36.6	36.9
9/24/77	MA2	4A	1122725	61	21.40	23.5	300	.7152	1.017	5128	1908.4	143.6	13.3

TABLE A-2. APPARENT DUST CONCENTRATIONS FROM PARTICULATE SIZING TESTS

Date	Time	Location	Actual flow (ft^3/min)	Corrected flow (SCFM)	Total volume (m^3 @ 20°C)	Concentration (mg/m^3)
9/19	10:24	Haul road	46.5	36.6	73.8	2.55
9/20	10:38	Haul road	36.5	28.6	52.8	2.00
9/21	8:42	Haul road	30	23.7	42.4	1.99
9/21	11:27	Haul road	30	23.7	62.3	1.41
9/22	9:18	Haul road	30	23.6	54.6	1.59
9/22	12:06	Haul road	30	23.6	25.1	0.34
9/26	12:16	Haul road	42	34.2	31.6	2.84
9/26	10:31	Haul road	43	35.0	26.4	1.83
9/26	1:54	Haul road	40	32.5	66.6	3.04
9/26	1:05	Haul road	40	32.5	29.1	25.9
9/19	1:59	Haul road	40	31.5	66.1	4.98
9/22	2:26	Haul road	30	36.1	30.4	0.84
9/26	11:10	Haul road	37.5	30.5	34.2	3.88
9/24	9:33	Crusher	32.5	26.6	64.0	3.49
9/26	7:54	Crusher	33	26.8	28.6	9.97
9/25	8:09	Crusher	36	29.5	28.1	6.69
9/25	8:54	Crusher	33	27.0	19.7	17.59
9/25	10:17	Crusher	32.5	26.6	20.1	13.45
9/25	10:54	Crusher	32.5	26.6	16.4	24.52
9/16	10:33	Mine	32.5	23.6	39.6	6.88
9/16	12:02	Mine	32.5	23.6	41.6	4.87
9/27	3:04	Mine	17.5	12.7	35.6	4.24
9/15	1:35	Mine	32.5	23.7	39.9	6.26
9/15	12:21	Mine	33.5	24.6	26.8	2.66
9/15	10:56	Mine	31.5	23.1	38.8	4.27
9/16	3:00	Mine	35	25.4	21.3	11.03
9/27	5:47	Mine	25.5	18.6	15.1	8.19
9/14	11:31	Retort discharge	43.5	35.4	59.5	17.08
9/14	2:16	Retort discharge	40	32.6	12.8	29.13
9/14	1:12	Retort discharge	40	32.6	24.6	23.16
9/27	11:49	Retort discharge	32	26	14.6	72.13
9/27	9:23	Retort discharge	37.5	30.5	13.7	43.60
9/27	10:37	Retort discharge	38.5	31.3	17.5	48.06
9/27	11:11	Retort discharge	35	28.5	16.7	37.93
9/27	10:02	Retort discharge	38.5	26.9	13.2	70.89
9/26	4:22	Retort discharge	37.5	30.5	33.3	39.81

TABLE A-3. MASS DISTRIBUTION ON CASCADE IMPACTOR PLATES

Date	Time	Location	Stage #1 (gm)	Stage #2 (gm)	Stage #3 (gm)	Stage #4 (gm)	Stage #5 (gm)	Stage #6 (gm)	Total weight (gm)
9/19	10:24	Haul road	0.0775	0.0194	0.0063	0.007	0.005	0.0729	0.1881
9/20	10:38	Haul road	0.0164	.0008	0.0056	0.001	0.006	0.0760	0.1058
9/21	8:42	Haul road	0.0320	0.0122	0.0008	0.0011	0.0001	0.0383	0.0845
9/21	11:27	Haul road	0.0015	0.0026	-	-	-	0.0836	0.0877
9/22	9:18	Haul road	0.0185	0.0064	0.0007	-	-	0.0610	0.0866
9/22	12:06	Haul road	0.0055	0.0025	0.0006	-	-	-	0.0086
9/26	12:16	Haul road	0.0189	0.0082	0.0053	.0038	0.0028	0.0506	0.0896
9/26	10:31	Haul road	0.0267	.0090	0.0049	0.0050	.0028	Neg. Wt.	0.0484
9/26	1:54	Haul road	0.0337	0.0160	0.0089	0.0110	0.0068	0.1262	0.2026
9/26	1:05	Haul road	0.6789	.0032	.0032	0.0039	0.0002	0.0644	0.7538
9/19	1:59	Haul road	0.0936	0.0296	0.0134	0.0079	0.0109	0.1738	0.3292
9/22	2:26	Haul road	0.0028	0.0011	-	-	0.0011	0.0205	0.0255
9/26	11:10	Haul road	0.0171	0.0092	0.0056	0.0026	0.0033	0.0948	0.1326
9/14	11:31	Retort discharge	0.3817	0.0666	0.0248	0.0284	0.0247	0.4903	1.0165
9/14	2:16	Retort discharge	0.1041	0.0166	0.0089	0.0146	0.0129	0.2158	0.3729
9/14	1:12	Retort discharge	0.0148	0.0785	0.0195	0.0250	0.0175	0.4145	0.5698
9/27	11:49	Retort discharge	0.6869	0.0821	0.0420	0.0498	0.0350	0.1573	1.0531
9/27	9:23	Retort discharge	0.2256	0.0398	0.0193	0.0191	0.0144	0.2791	0.5973
9/27	10:37	Retort discharge	0.3519	0.0524	0.0267	0.0311	0.0202	0.3588	0.8411
9/27	11:11	Retort discharge	0.2370	0.0297	0.0165	0.0191	0.0139	0.3173	0.6335
9/27	10:02	Retort discharge	0.3828	0.0678	0.0218	0.0280	0.0319	0.4034	0.9357
9/26	4:22	Retort discharge	0.5615	0.1116	0.0431	0.0394	0.0277	0.5425	1.3258

(continued)

TABLE A-3. MASS DISTRIBUTION ON CASCADE IMPACTOR PLATES (continued)

Date	Time	Location	Stage #1 (gm)	Stage #2 (gm)	Stage #3 (gm)	Stage #4 (gm)	Stage #5 (gm)	Stage #6 (gm)	Total weight (gm)
9/24	9:33	Crusher	0.0356	-	0.0079	0.0114	0.0104	0.1582	0.2235
9/26	7:54	Crusher	0.0352	0.0106	0.0109	0.0095	0.0100	0.2088	0.285
9/25	8:09	Crusher	0.0384	0.0110	0.0049	0.0038	0.0043	0.1256	0.1880
9/25	8:54	Crusher	.0904	0.0046	.0143	0.0306	.0198	0.1869	0.3466
9/25	10:17	Crusher	0.0592	0.0171	0.0125	0.0155	0.0149	0.1512	0.2704
9/25	10:54	Crusher	0.0986	0.0271	0.0178	0.0201	0.0167	0.2219	0.4022
9/16	10:33	Mine	0.0946	0.0614	0.0238	0.0118	0.0018	0.0791	0.2725
9/16	12:02	Mine	0.0669	0.0428	0.0152	0.0084	0.0071	0.0621	0.2025
9/27	3:04	Mine	0.0227	0.0271	0.0110	0.0086	0.0030	0.0784	0.1508
9/15	1:35	Mine	0.0888	0.0584	0.0175	0.0108	0.0104	0.0640	0.2499
9/15	12:21	Mine	0.0123	0.0141	0.0044	0.0025	0.0038	0.0342	0.0713
9/15	10:56	Mine	0.0382	0.0412	0.0138	0.0087	0.0075	0.0563	0.1658
9/16	3:00	Mine	0.1000	0.0630	0.0183	0.0090	0.0080	0.0367	0.235
9/27	5:47	Mine	0.0429	0.0190	0.0096	0.0091	0.0073	0.0358	0.1237

TABLE A-4. PERCENTAGE OF PARTICULATE BY WEIGHT ON EACH STAGE

	Date	Time	% In stage 1	% In stage 2	% In stage 3	% In stage 4	% In stage 5	% In stage 6
Haul road	9/19	10:24	41.2	10.3	3.3	3.7	2.7	38.8
	9/20	10:38	15.5	0.8	5.3	0.9	5.7	71.8
	9/21	8:42	37.9	14.4	0.9	1.3	0.1	45.3
	9/21	11:27	1.7	3.0	-	-	-	95.3
	9/22	9:18	21.4	7.4	0.8	-	-	70.4
	9/22	12:06	63.9	29.1	7.0	-	-	-
	9/26	12:16	21.1	9.2	5.9	4.2	3.1	56.5
	9/26	10:31	55.2	18.6	10.1	10.3	5.8	-
	9/26	1:54	16.6	7.9	4.4	5.4	3.4	62.3
	9/26	1:05	90.1	0.4	0.4	0.5	0.02	8.5
	9/19	1:59	28.4	9.0	4.1	2.4	3.3	52.8
	9/22	2:26	11.0	4.3	-	-	4.3	80.4
	9/26	11:10	12.9	6.9	4.2	2.0	2.5	71.5
Mine	9/16	10:33	34.7	22.5	8.7	4.3	0.6	29.0
	9/16	12:02	33.0	21.1	7.5	4.1	3.5	30.7
	9/27	3:04	15.1	18.0	7.3	5.7	2.0	52.0
	9/15	1:35	35.5	23.4	7.0	4.3	4.2	25.6
	9/15	12:21	17.3	19.8	6.2	3.5	5.3	48.0
	9/15	10:56	23.0	24.8	8.3	5.2	4.5	34.0
	9/16	3:00	42.6	26.8	7.8	3.8	3.4	15.6
	9/27	5:47	34.7	15.4	7.8	7.4	5.9	28.9
Retort discharge	9/14	11:31	37.6	6.6	2.4	2.8	2.4	48.2
	9/14	2:16	27.9	4.5	2.4	3.9	3.5	57.8
	9/14	1:12	2.6	13.8	3.4	4.4	3.1	72.7
	9/27	11:49	65.2	7.8	4.0	4.7	3.3	14.9
	9/27	9:23	37.8	6.7	3.2	3.2	2.4	46.7
	9/27	10:37	41.8	6.2	3.2	3.7	2.4	42.7
	9/27	11:11	37.4	4.7	2.6	3.0	2.2	50.1
	9/27	10:02	40.9	7.2	2.3	3.0	3.4	43.1
	9/26	4:22	42.4	8.4	3.3	3.0	2.1	40.9
Crusher	9/25	10:17	21.9	6.3	4.6	5.7	5.5	55.9
	9/25	10:54	24.5	6.7	4.4	5.0	4.2	55.2
	9/24	9:33	15.9	-	3.5	5.1	4.7	70.8
	9/26	7:54	12.4	3.7	3.8	3.3	3.5	73.3
	9/25	8:09	20.4	5.9	2.6	2.0	2.3	66.9
	9/25	8:54	26.1	1.3	4.1	8.8	5.7	53.9

TABLE A-5. LOWER SIZE LIMIT PARTICLE SIZING CUTOFFS (microns)

	Date	Time	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Haul Road	9/19	10:24	7.56	3.15	1.58	1.0	0.51
	9/20	10:38	8.64	3.6	1.8	1.14	0.59
	9/21	8:42	8.78	3.66	1.83	1.16	0.60
	9/21	11:27	8.78	3.66	1.83	1.16	0.60
	9/22	9:18	8.78	3.66	1.83	1.16	0.60
	9/22	12:06	8.78	3.66	1.83	1.16	0.60
	9/26	12:16	7.92	3.3	1.65	1.05	0.54
	9/26	10:31	7.92	3.3	1.65	1.05	0.54
	9/26	1:54	8.28	3.45	1.73	1.09	0.56
	9/26	1:05	8.28	3.45	1.73	1.09	0.56
	9/19	1:59	8.14	3.39	1.70	1.07	0.55
	9/22	2:26	7.56	3.15	1.58	1.00	0.51
	9/26	11:10	8.28	3.45	1.73	1.09	0.56
Retort	9/14	11:31	7.63	3.18	1.59	1.01	0.52
	9/14	2:16	8.28	3.45	1.73	1.09	0.56
	9/14	1:12	8.28	3.45	1.73	1.09	0.56
	9/27	11:49	9.0	3.75	1.88	1.20	0.62
	9/27	9:23	8.28	3.45	1.73	1.09	0.56
	9/27	10:37	8.14	3.39	1.70	1.07	0.55
	9/27	11:11	8.64	3.60	1.8	1.14	0.59
	9/27	10:02	8.86	3.69	1.86	1.18	0.61
	9/26	4:22	8.28	3.45	1.73	1.09	0.56
Crusher	9/24	9:33	8.86	3.69	1.86	1.18	0.61
	9/26	7:54	8.86	3.69	1.86	1.18	0.61
	9/25	8:09	8.50	3.54	1.79	1.13	0.59
	9/25	8:54	8.86	3.69	1.86	1.18	0.61
	9/25	10:17	8.86	3.69	1.86	1.18	0.61
	9/25	10:54	8.86	3.69	1.86	1.18	0.61
Mine	9/16	10:33	8.78	3.66	1.83	1.16	0.60
	9/16	12:02	8.78	3.66	1.83	1.16	0.60
	9/27	3:04	12.96	5.46	2.76	1.77	0.92
	9/15	1:35	8.78	3.66	1.83	1.16	0.60
	9/15	12:21	9.0	3.75	1.88	1.19	0.61
	9/15	10:56	9.07	3.78	1.89	1.21	0.62
	9/16	3:00	9.0	3.75	1.88	1.19	0.61
	9/27	5:47	10.66	4.44	2.24	1.43	0.74

TABLE A-6. OPTICAL SIZING OF SELECTED FILTERS FROM PARTICULATE SEPARATION TESTS

Sample location		0-1.0μ	1.0-2.0μ	2.0-3.0μ	3.0-8.0μ	over 8.0μ
Retorted shale transfer	No. %	21.78	18.05	14.61	36.10	9.46
	Wt. %	0.02	0.35	1.32	34.83	63.47
Haul road	No. %	16.21	19.88	13.46	35.47	14.98
	Wt. %	0.01	0.29	0.89	25.08	73.73
Crusher area	No. %	19.25	17.08	10.56	40.37	12.73
	Wt. %	0.01	0.27	0.76	30.98	67.98
Mine adit no. 1	No. %	72.85	8.61	2.65	10.93	4.97
	Wt. %	0.12	0.38	0.54	23.77	75.19

Polarized light microscopy performed by Walter C. McCrone Associates

TABLE A-7. TRAFFIC RECORDS FOR HAUL ROAD AND MINE

Date	Location	Filter No.	Traffic	
			Up	Down
9/19/77	Road	1125571	2:01 2:21 2:25 2:35	2:06 2:11 2:53
9/20/77	Road	1125546		
9/20/77	Road	16	10:30 10:51 11:32 11:35	10:42 11:09 11:12
9/20/77	Road	10	1:35 2:29 2:31	2:10 2:14 3:06 3:10
9/20/77	Road	9	10:50 10:51 11:31 11:34	10:42 11:09 11:12
9/20/77	Road	34	1:35 2:29 2:31	2:10 2:14 3:06 3:10
9/20/77	Road	1125508	12:08 12:36 12:38 1:08	11:57 12:10 12:12 12:35 1:14 1:17
9/20/77	Road	1125527	10:50 10:51 11:31 11:34	10:42 11:09 11:12
9/20/77	Road	33	1:33 1:36 2:30 2:32	2:11 2:14 3:07 3:10

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			Up	Down
9/20/77	Road	1125505	12:08 12:36 12:38 1:08	11:57 12:10 12:12 12:35 1:14 1:17
9/20/77	Road	1125507	12:36 12:38 1:08	12:10 12:12 12:35 1:14 1:17
9/21/77	Road	1125539	2:08 2:12 2:19	2:20 2:42 3:03 3:08
9/21/77	Road	1125534		2:40 3:01 3:07
9/21/77	Road	112536		2:40 3:01 3:07
9/21/77	Road	1125535		2:40 3:01 3:07
9/21/77	Road	1125503	10:26 10:29	10:14 10:50 11:02 11:02 11:07
9/21/77	Road	1125578	10:26 10:29	10:14 10:50 11:02 11:02 11:07

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			Up	Down
9/22/77	Road	112560		
9/22/77	Road	1125560		
9/22/77	Road	39		
9/22/77	Road	40	10:43 10:47 11:26 11:41 11:43 11:49	11:15 11:25 11:32
9/22/77	Road	1122717		
9/22/77	Road	1125558		
9/22/77	Road	1122713		
9/22/77	Road	1122721		
9/22/77	Road	1122715		
9/22/77	Road	1122719		
9/22/77	Road	1122716		
9/22/77	Road	1125561		
9/22/77	Road	1125562		
9/22/77	Road	1125530	12:35 12:40 12:42	12:18 12:25 12:27
9/22/77	Road	1125568	12:35 12:40 12:42	12:18 12:25 12:27
9/22/77	Road	1122720	2:27 2:30	3:02 3:11

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			Up	Down
9/22/77	Road	1122718	1:32 1:38 1:41	1:12 1:20 1:22 1:46 2:06 2:16 2:18
9/22/77	Road	101	10:44 11:26 11:38 11:39 11:41	10:45 11:12 11:23 11:30
9/22/77	Road	98	1:30 1:35 1:37 2:07	1:09 1:18 1:20 1:45 2:03 2:14 2:16
9/22/77	Road	100	10:44 11:26 11:38 11:39 11:41	10:45 11:12 11:23 11:30
9/22/77	Road	1125563	9:39 9:44 9:55	9:19 9:24 9:30 10:20 10:25 10:27
9/22/77	Road	1122714	12:38 12:43 12:44	12:20 12:27 12:29
9/26/77	Road	87	1:27 1:31 1:35	1:10 1:13 1:18 1:19

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			Up	Down
9/26/77	Road	36	2:02 2:19 2:22 2:28	2:02 2:06 2:11 2:56 3:00 3:09
9/26/77	Road	88	12:34 12:36 12:43	12:17 12:21 12:26
9/26/77	Road	47	10:48 10:51 10:57	10:32 10:36 10:40 10:58
9/26/77	Road	89	11:42 11:43 11:50	11:25 11:28 11:38
			In	Out
9/02/77	Mine	1122757		
9/07/77	Mine	1122760		
9/07/77	Mine	1122762		
9/07/77	Mine	1122750		
9/07/77	Mine	1122746		
9/14/77	Mine	1122785	3:19 3:41 3:42 3:44	3:56 4:00 4:07
9/14/77	Mine	1125531	1:18 1:27	1:40 1:48

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			In	Out
9/14/77	Mine	1122793		10:20 11:40
9/14/77	Mine	1122776	1:32	1:23 1:28
9/14/77	Mine	1122786	4:05	3:52
9/14/77	Mine	1122792		
9/14/77	Mine	1125501		12:17
9/14/77	Mine	1125594		
9/14/77	Mine	1125595	2:31 2:41	2:45 2:55 2:58
9/14/77	Mine	1125532	12:04 12:11 12:19 12:31	12:26
9/15/77	Mine	1125573	11:45	11:48 11:49 12:05 12:09 12:15 12:16
9/15/77	Mine	112b591	1:52 1:56 2:00	1:32
9/15/77	Mine	1122791	11:36 11:47 11:59 11:59 12:03	11:45
9/15/77	Mine	1125600	2:32 2:47 2:53 2:55	

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			In	Out
9/15/77	Mine	1122758	10:45 10:47 11:02 11:12	10:50
9/15/77	Mine	1125574	11:05 11:15 11:39 11:51	11:17
9/15/77	Mine	1122728	1:14	1:18 1:35 2:00 2:04
9/15/77	Mine	1122748	11:00	10:21 10:34 10:08 11:13 11:13 11:22
9/15/77	Mine	1125592	2:38	3:05
9/15/77	Mine	1125589		
9/15/77	Mine	1125590		
9/15/77	Mine	1125582		
9/15/77	Mine	1125572	1:55 2:00 2:05	
9/16/77	Mine	1125569		
9/16/77	Mine	1125510		11:57 12:02 12:04 12:06

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			In	Out
9/16/77	Mine	1125508	10:49	10:40 10:51 10:58 10:57 11:19
9/16/77	Mine	1125512	12:40	12:48 12:51 12:55
9/16/77	Mine	1125509	11:21 11:51 11:52	
9/16/77	Mine	1125586		9:57 10:00 10:02 10:08
9/16/77	Mine	1125587	10:45 10:45 10:49 11:08	
9/16/77	Mine	1125585	9:54 9:54 9:58	
9/16/77	Mine	1125513		1:42 1:46 1:51 1:53
9/16/77	MIne	1125514	1:34 1:36 1:38 2:10	
9/16/77	Mine	1125511	12;40 12:41 12:45 1:01	1:12

(continued)

TABLE A-7. TRAFFIC RECORDS FOR HAUL AND ROAD MINE (continued)

Date	Location	Filter No.	Traffic	
			In	Out
9/16/77	Mine	1125584	12:40 12:41 12:45 1:01	
9/16/77	Mine	1125517	10:45 10:45 10:49 11:08	
9/23/77	Mine	42		
9/23/77	Mine	2		
9/27/77	Mine	41	3:22	3:21
9/27/77	Mine	17		3:16
9/27/77	Mine	71	3:22	3:21
9/27/77	Mine	23		
9/27/77	Mine	18		

TABLE A-8. EQUIPMENT LIST

Meteorological Equipment

- 2 - MRI model 1071 mechanical weather stations monitors and record wind run, direction, and temperature
- 1 - Sling psychrometer
- 1 - Barometer

Other Equipment

- 8 - General Metal Works high volume samplers model 2000 (40 CFM)
- 5 - General Metal Works Accu-Vol high volume samplers model 2310 (40 CFM)
- 1 - Onan 3 KW generator
- 1 - Sierra Instruments 5 stage high volume cascade impactor, model 235 (40 CFM)
- 1 - Velometer
- 2000 feet of 12/3 extension cord
- 200 Gelman spectrograde glass fiber filters - 8" x 10"
- 200 Whatman 41 cellulose filters - 8" x 10"
- 1 - Mettler P-5 balance
- 1 - Dessicator

APPENDIX B

INORGANIC ANALYSES

SAMPLE PREPARATION

The polyethylene bags containing dust samples from Whatman filters were hand-carried to the inorganic analysis laboratory where they were logged in along with stabilized filter tare weights. The filters were stabilized under identical temperature and humidity conditions and weighed to ± 0.1 milligrams.

Where sample weights were over 10 grams, a portion of the particulate was weighed for analysis. On all other filters, one-half of the area was digested for trace and major metals analysis, one-eighth of the area was digested for mercury analysis, one eighth of the area was digested for sulfur analysis, and one eighth of the area was fused for silicon and fluoride analyses. The net sample weights varied from 21 milligrams to 13.2 grams, so that analysis accuracy varied considerably as a function of available sample.

All samples to be analyzed for As, Al, Ca, Cd, Cr, Cu, Fe, Mg, Na, Ni, Pb, Se, V, and Zn were digested to completion at 95°C in a 1:1 mixture of nitric acid, hydrochloric acid, and perchloric acid. Samples for mercury analysis were digested in a 1:3 aqua regia mixture of nitric and hydrochloric acid for two minutes at 95°C followed by permanganate-persulfate oxidation. A sodium hydroxide-magnesium oxide fusion was used to decompose samples for analysis of Si and F. Sulfur was determined by a gravimetric method after dissolution and oxidation by bromine to sulfate and precipitation as barium sulfate. The digested samples were all brought to a 50 mililiter volume for analysis.

ANALYSIS METHODOLOGY

The methodology used for each inorganic constituent is given in Table B-1, together with references for each standard method and the detection limit in milligram/liter. All related data were recorded in the analyst's laboratory notebook, including:

1. Analysis being performed (procedure document number and title)
2. Pertinent information about procedure, reagents, etc.
3. Sample identification (project number and filter number)
4. Dilutions of sample, if any
5. Data resulting from analysis (absorbance readings, milligrams of precipitate, etc.)
6. Data for quality control blanks, standards and calibration
7. Sample calculations including background corrections
8. Results

TABLE B-1. ANALYSIS METHODS

Parameter	Description of method	References	Detection limit mg/l
Aluminum	flame atomic absorption	1,2,7	0.1
Arsenic	flameless atomic absorption with $NiNO_3$ using standard additions	3,4,5,6	0.002
Cadmium	flame atomic absorption	2,7	0.002
Calcium	flame atomic absorption	2,7	0.05
Chromium	flame atomic absorption	2,7	0.01
Copper	flame atomic absorption	2,7	0.01
Fluoride	specific ion electrode	2	0.1
Iron	flame atomic absorption	2,8	0.01
Lead	flame atomic absorption	2,8	0.01
Magnesium	flame atomic absorption	2,7	0.05
Manganese	flame atomic absorption	2,7	0.005
Mercury	cold vapor atomic absorption	2,5	0.00002
Nickel	flame atomic absorption	2,7	0.01
Selenium	flameless atomic absorption with $NiNO_3$ using standard additions	3,4,5,6	0.005
Silica	colorimetric, ammonium molybdate	1,2	1
Sodium	flame emission	7	0.1
Sulfate (from sulfate)	$BaSO_4$ precipitate	1,2	10
Vanadium	flameless atomic absorption	5,6	0.005
Zinc	flame atomic absorption	2,7	0.005

9. Information such as wave length, cell size, zero reference solution, sample size.

A "Standard Additions" technique was used in the case of suspected interferences (example: As and Se determinations by flameless atomic absorbtion). In the standard addition method, equal volumes of sample are added to a deionized distilled water blank and to three standards containing different known amounts of the test element. The absorbance of each solution is determined and then plotted on the vertical axis of a graph, with the concentrations of the known standards plotted on the horizontal axis. When the resulting line is extrapolated back to zero absorbance, the point of interception of the abscissa is the concentration of the unknown.

The quantity of each constituent (in milligrams) was determined from the measured concentrations and known liquid sample volumes. These values were then converted to particulate ppm concentrations by using the sample weight determined prior to sample preparation steps.

QUALITY CONTROL AND ASSURANCE

A new clean Whatman filter blank (for high-volume applications) was processed through the identical analysis sequence. Whenever blank values were significant, they were subtracted from the raw analytical measurements.

To provide further evaluations of analytical accuracy and precision, 10% of all analyses were repeated and another 10% were spiked. This was consistent with routine procedures conducted by the inorganic chemical laboratory.

The computed values of elemental compositions of the dust samples were compared for internal consistency. One small sample of only 2 milligrams was analyzed, but the results were a factor of ten higher than comparable samples, so the data were not reported. It would have been difficult to make a judgement on inadequate sample size without such a sizable data base.

ANALYSIS PRECISON ESTIMATES

Quality control limits were based upon actual performance at CDM/Acculabs. Typically more than 50 data points were used to generate the limits of 2σ as a "warning limit" and 3σ as a "control limit". For the purpose of determining precison, the quantity "% deviation" is calculated as follows:

$$\% \text{ Deviation} = \frac{(X_1 - X_2) \cdot 100}{(\overline{X_1 + X_2}) \cdot 1/2} \qquad \text{where X is } \mu g/ml$$

Example: $X_1 = \frac{\text{Run 1}}{2.9}$ $X_2 = \frac{\text{Run 2}}{3.2}$

$$\% \text{ Deviation} = \frac{\left(\frac{3.2 - 2.9}{3.2 + 2.9}{2}\right) \times (100)}{} = 9.8\% \text{ for two repeated analyses}$$

For the purpose of determining accuracy, the quantity "% recovery" is calculated as follows:

$$\% \text{ recovery} = \frac{\text{Concentration found}}{\text{Concentration expected}} \times 100 = \frac{\text{mass found}}{\text{mass expected}} \times 100$$

Example: Ca = 5.9 µg/ml (100 ml solution spike with 1,000 ml of 500 µg/ml soln.

Calcium in original solution = 5.3 µg/ml x 100 ml = 530 µg Ca

Calcium added 500 µg/ml x 1.000 ml = 500 µg

- determine 10.0 µg/ml in 101 ml = 1010 µg
- find 1010 µg Ca
- expect to find 500 + 530 = 1030 µg Ca

$$\% \text{ recovery} = \frac{1010}{1030} \times 100 = 98\%$$

The data control limits indicated in Table B-2, below, have been accumulated on samples in the range from the detection limit to 100 times the detection limit.

TABLE B-2. INORGANIC ANALYSIS TEST LIMITS

Component	% Mean Recovery	% Deviation 2σ	% Deviation 3σ
As	113%	32%	47%
Al	103	38	57
Ca	102	9	14
Cd	106	30	46
Cr	75	48	72
Cu	96	29	44
Fe	103	48	72
Mg	102	12	18
Na	102	17	25
Ni	106	43	65
Pb	103	46	69
Se	113	17	27
V	97	12	18
Zn	108	48	73
Si	93	12	18
S	103	22	34
F	112	33	50
Hg	101	80	120
Mn	104	11	16

Table B-2 indicates that repeated arsenic (As) analyses, for example, will statistically lie outside the 2σ control limit of 32% deviation only 1 in 20 times. The control limit band is then ± 16% around the mean value. At the 3σ level, only 1 in 500 arsenic analyses are expected to fall outside the 47% deviation band.

The following arsenic values were obtained from five separate samples taken downwind of the retorted shale transfer point:

5.5, 45.9, 5.4, 5.1, and 12.9 ppm.

The high value of 45.9 ppm is not within a 3σ analysis precison of 47% of the apparent midrange (5 - 15 ppm) of the other sample analyses so it can be argued that the high value indicates a real variation in the arsenic content of the retorted shale dust at the time the second sample was taken. Similar comparisons can be made for other elemental analyses of the various dust samples.

Table B-3 summarizes all inorganic analyses that were performed for nineteen constituents. The location codes are consistent with Table A-1.

TABLE B-3. PARAHO FUGITIVE DUST ELEMENTAL ANALYSIS (UNITS IN PPM)

Net Wt. (g)	Filter No./Date	Location	Cd	Ca	Cr	Cu	Fe	Mg	Na	Ni	Pb
0.2389	93-9/24	CDW	ND	56,100	29	76	11,300	1,900	8,080	23	33
4.4011	21-9/21	CDW	ND	1,210	1.2	3.9	27,000	39,000	18,000	0.6	ND
0.0580	92-9/24	CUW	1	35,300	72	72	6,640	6,640	4,200	3.3	94
1.0187	82-9/26	RDW	2	281,000	12	75	21,100	36,700	6,880	30	44
13.2218	8-9/15	RDW	21	91,500	21	60	21,700	24,300	6,850	30	47
4.3699	1-9/9	RDW	4.5	45,300	52	47	21,900	33,800	28,400	36	63
0.0596	70-9/27	RDW	1	97,200	13	68	17,900	36,200	6,500	24	36
0.5482	79-9/26	RDW	2	98,000	11	64	17,800	34,700	5,980	26	40
0.0589	84-9/26	RDW	ND	20,700	75	110	6,300	6,710	83,200	32	102
0.0439	4-9/26	RUW	2	170,000	ND	390	33,900	61,700	26,900	638	296
0.6390	20-9/27	MA 1	1	73,200	12	146	11,100	28,500	17,060	13.1	56
0.1351	90-9/27	MA 1	11	500,000	64	14,700	79,200	172,000	112,000	141	750
0.1737	19-9/27	MA 2	5	73,700	20	210	17,700	23,100	74,300	33	92
1.3246	67-9/27	MA 2	2	80,000	9	78	13,400	30,800	20,200	16	66
0.0883	12-9/20	HRDW	3	96,700	69	147	31,700	34,100	11,100	44	102
0.0913	36-9/20	HRDW	2.9	91,700	ND	175	24,200	29,400	29,400	55	55
0.0212	26-9/21	HRDW	ND	58,500	19	76	12,900	88,200	20,500	31	130
4.5232	2-9/9	SRBH	6.7	67,300	47	64	23,700	47,400	25,300	36	65
4.6322	3-9/13	SRBH	5.9	59,000	60	48	22,300	36,200	31,800	36	64
4.5582	6-9/14	SRBH	6.1	61,300	56	48	22,300	33,900	29,200	45	62

(continued)

TABLE B-3. PARAHO FUGITIVE DUST ELEMENTAL ANALYSIS (UNITS IN PPM) (continued)

Net Wt. (g)	Filter No./Date	Location	V	Zn	Mn	Al	As	Se	Si	S	F	Hg
0.2389	93-9/24	CDW	44	319	263	5,876	7.5	20.9	56,900	460	1,440	23
4.4011	21-9/21	CDW	4.5	3	6.7	16,500	0.11	1.1	181,300	25	50	0.01
0.0580	92-9/24	CUW	16	198	152	48,000	2.4	22.4	37,700	5,000	9,000	-
1.0187	82-9/26	RDW	140	157	396	8,181	5.5	3.3	45,560	1,730	360	0.04
13.2218	8-9/15	RDW	130	134	359	10,210	45.9	14.7	45,300	5,600	1,130	0.31
4,3699	1-9/9	RDW	243	140	-	42,700	12.9	30	34,700	26	574	0.34
0.0596	70-9/27	RDW	34	282	364	10,080	5.4	5.4	65,400	8,800	1,620	0.06
0.5482	79-9/26	RDW	110	182	354	7,000	5.1	5.1	14,600	10,200	2,770	0.08
0.0589	84-9/26	RUW	13	830	120	4,650	1.7	5.1	54,000	5,600	3,510	-
0.0439	4-9/26	RUW	108	455	665	21,460	11.4	6.8	290,000	2,500	6,180	0.9
0.6390	20-9/27	MA 1	28	110	266	11,500	11.6	1.7	81,200	10,800	2,190	0.06
0.1351	90-9/27	MA 1	440	1,303	2,320	69,670	60.7	22.2	435,000	65,100	4,590	0.3
0.1737	19-9/27	MA 2	49	260	402	15,000	6.9	9.8	110,000	23,600	1,750	0.23
1.3246	67-9/27	MA 2	68	118	325	13,043	0.9	4.4	59,600	8,600	1,570	0.03
0.0883	12-9/20	HRDW	74	154	539	36,590	11.3	18.1	227,000	1,250	3,180	0.5
0.0913	36-9/20	HRDW	63	386	616	29,240	16.5	51.5	Major	2,400	20,700	0.4
0.0212	26-9/21	HRDW	35	61	355	15,390	21	-	670,000	5,200	8,520	1.9
4.5232	2-9/9	SRBH	308	140	-	41,900	20.0	30	43,700	7,800	1,787	0.48
4.6322	3-9/13	SRBH	243	130	-	42,200	16.1	33	14,400	5,300	517	0.25
4.5582	6-9/14	SRBH	132	225	-	41,000	13.5	43	93,000	6,100	622	0.28

Filter 90 data were not included in averages reported in Table 6 because the calcium, magnesium and silica values add to >100% (sample accuracy is ±50%).

REFERENCES

1. "Standard Methods for the Examination of Water and Wastewater", 14th edition, 1975.

2. "Methods for Chemical Analysis of Water and Wastes" USEPA, 1974 (EPA-625-16-74-003).

3. "Determining Selenium in Water, Wastewater, Sediment, and Sludge by Flameless Atomic Absorption Spectroscopy", Martin & Kopp, AA Newsletter v.14, no. 5, 1975.

4. "Atomic Absorption Analysis with the Graphite Furnace using Matrix Modification", Ediger, AA Newsletter v.14, no. 5, 1975.

5. Federal Register, Part II, EPA Water Programs, "Guidelines Establishing Test Procedures for the Analysis of Pollutants", December 1, 1976.

6. "Analytical Methods for Atomic Absorption Spectrophotometry using the HGA Graphite Furnace", 1972.

7. "Analytical Methods for Flame Spectroscopy", Varian.

8. Technicon Autoanalyzer, Industrial Method No. 100-70 W "Nitrate and Nitrite in Wastewater".

APPENDIX C

ORGANIC ANALYSES

EXTRACTIONS

At the laboratory, the sample bags were opened 24 hours prior to extraction and the samples were again desiccated. The samples were not reweighed prior to extraction. Samples awaiting extraction were stored in a cool dark sample storage room specifically set aside as a solvent and vapor-free area. Past experience has shown retorted shale samples to absorb large amounts of volatile compounds when present even in trace amounts in the ambient storage atmosphere.

Burdick and Jackson® "Distilled in Glass" methylene chloride was used for all of the extractions. All solvent batches were tested for residues by evaporation of twice the amount of solvent that would be used at any point in the extraction or elution process. Evaporation was done in a rotary evaporator at a low temperature and reduced pressure. Cumulative solvent residues did not exceed 5% of the minimum amount of extracted material in any case and were in most cases well below 0.1% of the extract by weight.

Soxhlet extraction apparatus and cellulose Soxhlet thimbles were all thoroughly cleaned with a 24-hour extraction cycle in methylene chloride prior to usage. The extractors used for these samples were large-size, 300 milliliter capacity units. The size of these extractors, although large in comparison to the size of many of the samples, was necessary in order to adequately hold the larger samples. The small samples, some weighing only 182 milligrams were completely held within the matrix of their Fiberglass filters. The filter itself when folded up occupied between 1/3 to 1/2 of the Soxhlet thimble volume. Samples were loaded into the prewashed Soxhlet thimbles directly from their plastic shipping bags. Since the bags had not been previously cleaned with solvent, no attempt was made to wash residual sample from the bag. In some cases this would produce a small error in the sample weights used in calculating the percent solvent extractable.

The solvent reservoirs used with these extractors were 2 liter flasks and were filled with approximately 800 milliliters of solvent. Condensers for the Soxhlet systems were cooled with recirculating water-ethylene glycol solution which is held at 0°C. This low temperature assured that volatile components could not be lost during extraction. All ground glass standard taper joints were fitted together in a dry state and no lubricants were used. All Soxhlet extractions were carried out in total darkness and all subsequent extract handling was done under subdued indirect incandescent lighting.

After extraction, the extracts were reduced in volume on a specially designed rotary evaporator at a low temperature and reduced pressure. The condenser was operated at 0°C and the receiving flask was kept below -5°C. The extract itself was held at a constant 15°C in a temperature controlled water bath. The rotating joint in this system was composed of two glass ball joints and a Teflon interface joint. No lubrication was needed or used on this joint. The extracts were each reduced to a volume of about 10 mililiters and then filtered through 0.5 micrometers. Fluoropore® Teflon filters were then washed into preweighed glass test tubes where they were taken to constant weight "dryness" under a stream of purified dry nitrogen. Temperature was maintained at 20°C. Successive weighings over a one to two week period assured constant weight had been reached on all samples. All weighings were made to within ± 0.00003 grams with triplicate final weights being recorded.

FRACTIONATION

Standard 25 centimeter x 1 centimeter ID glass chromatography columns fitted with Teflon fittings and Teflon stopcocks were used. A glass frit sits on the bottom of the column to retain the absorbent. No lubricants were used for column fittings or stopcocks. The absorbent material used was 60-200 mesh silica gel that had been heated to 200°C for 24 hours prior to column packing. The silica gel was then cooled in a desiccator. 13.5 ± 0.2 grams of this material was slurried with approximately 40 milliliters of methylene chloride that had been deaerated by bringing to a near boil for several minutes. This slurry was then poured into the glass column and the system was vibrated while the excess solvent was slowly allowed to drain out of the column. At no time was the solvent allowed to drop below about 0.5 centimeters above the top of the absorbent bed.

The use of deaerated solvents greatly reduced the problem of air bubble formation in the column packing procedures. Column height after final settling of the absorbent material was 22.5 ± 0.5 centimeters. After packing, the columns were prepared by eluting them with the following solvents.

1. 100 milliliters methanol
2. 25 milliliters methlyene chloride
3. 25 milliliters n-hexane

In most cases less than 500 milligrams of sample extract was available for fractionation. For extracts weighing more than 500 milligrams, an aliquot of slightly less than 500 milligrams was removed using a micro spatula. To each of these extracts 0.5 milliliters of methylene chloride was added and allowed to sit with the extract for 15 to 20 minutes in order to solubilize the entire "dried" mass. To this solution, 0.5 grams of the activated silica gel was added and thoroughly mixed. This combination was then washed onto the top of the column in n-hexane. Elution was carried out using the solvents shown in Section 3. Each eluted fraction was collected in a numbered, solvent-washed, and pre-weighed aluminum micro weighing pan. The eluted fractions were then allowed to go to constant weight dryness at 20°C. Final weights were recorded

to within ± 30 micrograms. The range of extract weights was from between 180 micrograms and 0.47 grams. A ninth fraction represented materials that were not recovered from the column. This was determined by taking the differences between the amount of material placed on the column and the summation of all fraction weights removed from the column. For the most part, this fraction consisted of materials bound to the column packing and not eluted by the methanol. All data are listed in Tables C-1, C-2 and C-3.

In addition to the collected particulate samples, three other samples were extracted and fractioned in an identical manner for comparison. Two samples were in bulk form, having been dumped from the surface of several high-volume filters collected in highly dust laden areas. One sample consisted of raw shale dust from the screening room. The other sample had been collected next to the pilot plant retort diverter belt just prior to the chute running to the screw conveyor system. Both of these samples were collected in March of 1976.

The complete analysis of a blank high-volume filter was made for the purpose of quality control. Extraction, extract handling, weighing, and fractionation was performed on this sample in a manner identical to the rest of the filters. Of the 8.3 milligrams of material extracted from the filter, most of this material was eluted in the first fraction of the fractionation scheme. Infrared analysis of this fraction revealed it to be composed almost entirely of silicon oils.

INFRARED ANALYSIS

As previously mentioned, the Level 1 sample fractionation scheme is a fairly low resolution process with overlap between fractions. It was felt that perhaps a better insight into the composition of these samples, as well as the fractionation scheme itself, could be realized by the inclusion of a few rapid infrared absorption analysis on some of the samples.

Infrared analysis was performed on a Beckman IR8 spectrophotometer. Data collection for the spectra printed in this report was performed by a HP9825 calculator system. In order to provide sufficient material for rapid IR analysis, same-numbered fractions from similar sample types were combined. Three categories of similar sample types were used; namely: mine related samples, raw shale samples, and retorted shale samples. The newly combined fractions were spotted on salt plates in a carbon tetrachloride solution and allowed to dry thoroughly before analysis. The infrared spectra of fraction numbers 1, 2, and 5 are shown in Figures C-1 to C-3.

Silicon oils, frequently used as lubricants in the manufacture of glass filament products such as the high-volume filters, as well as stopcock greases, have a very characteristic set of infrared absorptions. These are at 795, 1020, 1080, 1260 and 2960 centimeters^{-1}, being due to the various Si-O, Si-C, C-O and C-H bonds present in these compounds. Unfortunately, the spectra of all of the separated fractions exhibited these bands to some degree, including the spectra of the procedural blank high-volume filter, where they are the only bands present. In view of this and the fact that solvent residues did not contain these materials and no silicon lubricants were used anywhere in

the analytical procedure, the most likely source of thes compounds would be the high-volume filters themselves. This contamination hindered the interpretation of all but the strong features in the infrared spectrum of these samples.

It is evident that in progressing through the series of L.C. fractions that the aliphatic hydrocarbon-dominated first fractions gradually gives way to more and more polar organic compounds in the latter fractions. This is shown by the increase in the 3500-2500 centimeter^{-1} region (alcohols, phenols, carboxylic acids, and others) and in the 1750-1550 centimeter^{-1} region (esters, ketones, acids, olefins, and nitrogen-containing compounds).

Interpretation of the dominant features of the infrared absorbance spectra of L.C. fractions 1, 2 and 5 from each of the three sample categories are listed below, but the characterizations should not be treated as conclusive.

Mine L.C. fraction 1 --
Long chain aliphatic hydrocarbons with a slight amount of hydroxyl and aromatic compounds.

Raw shale L.C. fraction 1 --
Long chain aliphatic hydrocarbons constitute possibly 90% of this sample. The remainder may be a combination of hydroxyl (3150 cm^{-1}), carboxylic acid (1705 cm^{-1}), and olefinic (1600 cm^{-1}), compounds. A small amount of aromatic character seems to be evident in this group. This is a very complex mixture.

Retorted shale L.C. fraction 1 --
Essentially the same remarks apply to this fraction as for Fraction 1 of the raw shale sample. The mixture, however, is less complex due to the absence of a number of bands and the presence of no new bands.

Mine, raw shale, and retorted shale L.C. fractions 2 --
This group of fractions shows little difference between each other. They are essentially identical to Fraction 1 of the raw shale sample above.

Mine, raw shale, and retorted shale L.C. fractions 5 --
Very broad bands in the 3500-2500 and 1750-1550 centimeter^{-1} regions are an indication of a complex misture of many oxygen-containing organic species, particularly alcohols, phenols, carboxylic acids, ketones, and esters, all dominated by large amounts of aliphatic hydrocarbon structures, with relatively small amounts of aromatic structures.

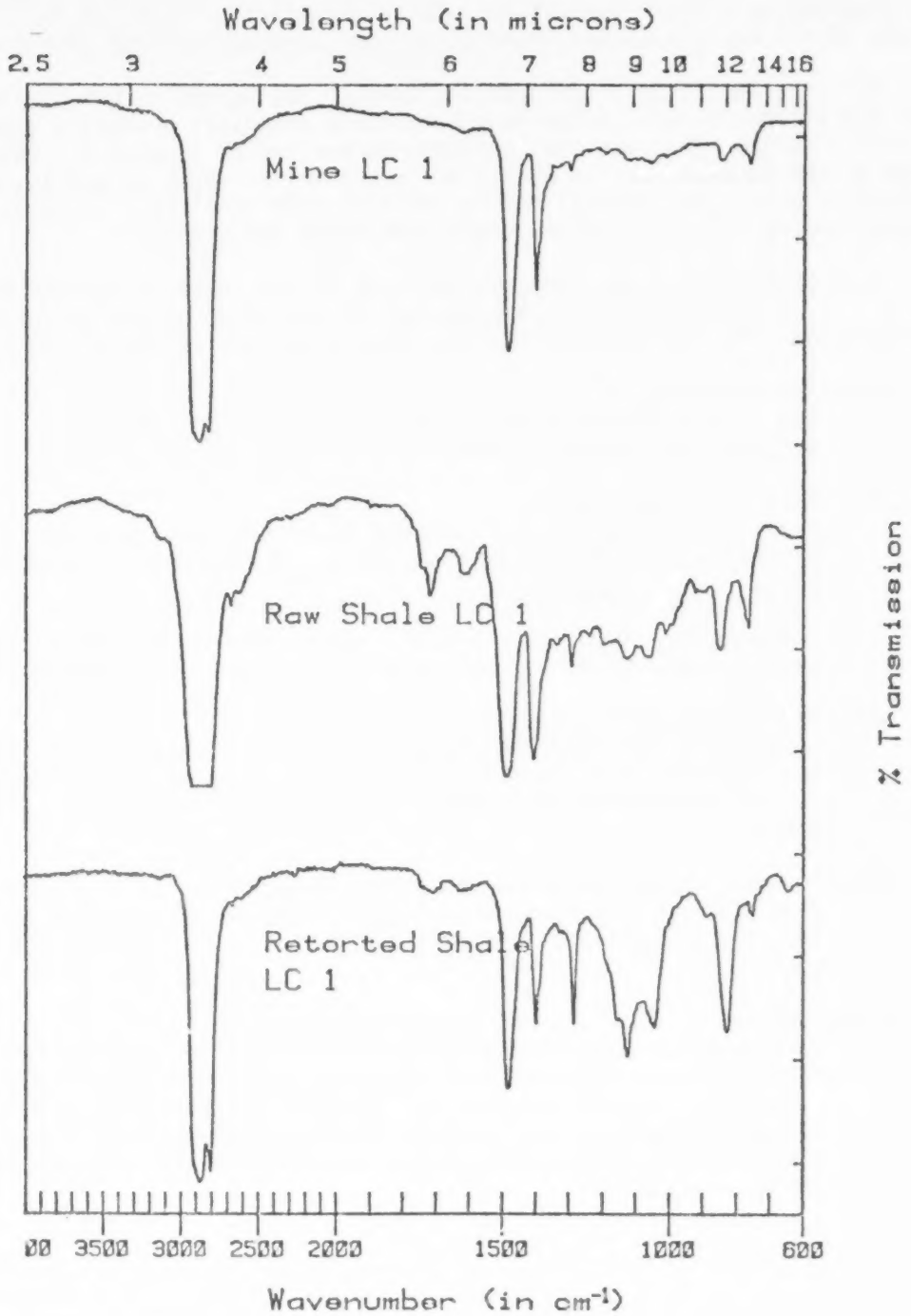

Figure C-1. Infrared spectra of L.C. fraction 1.

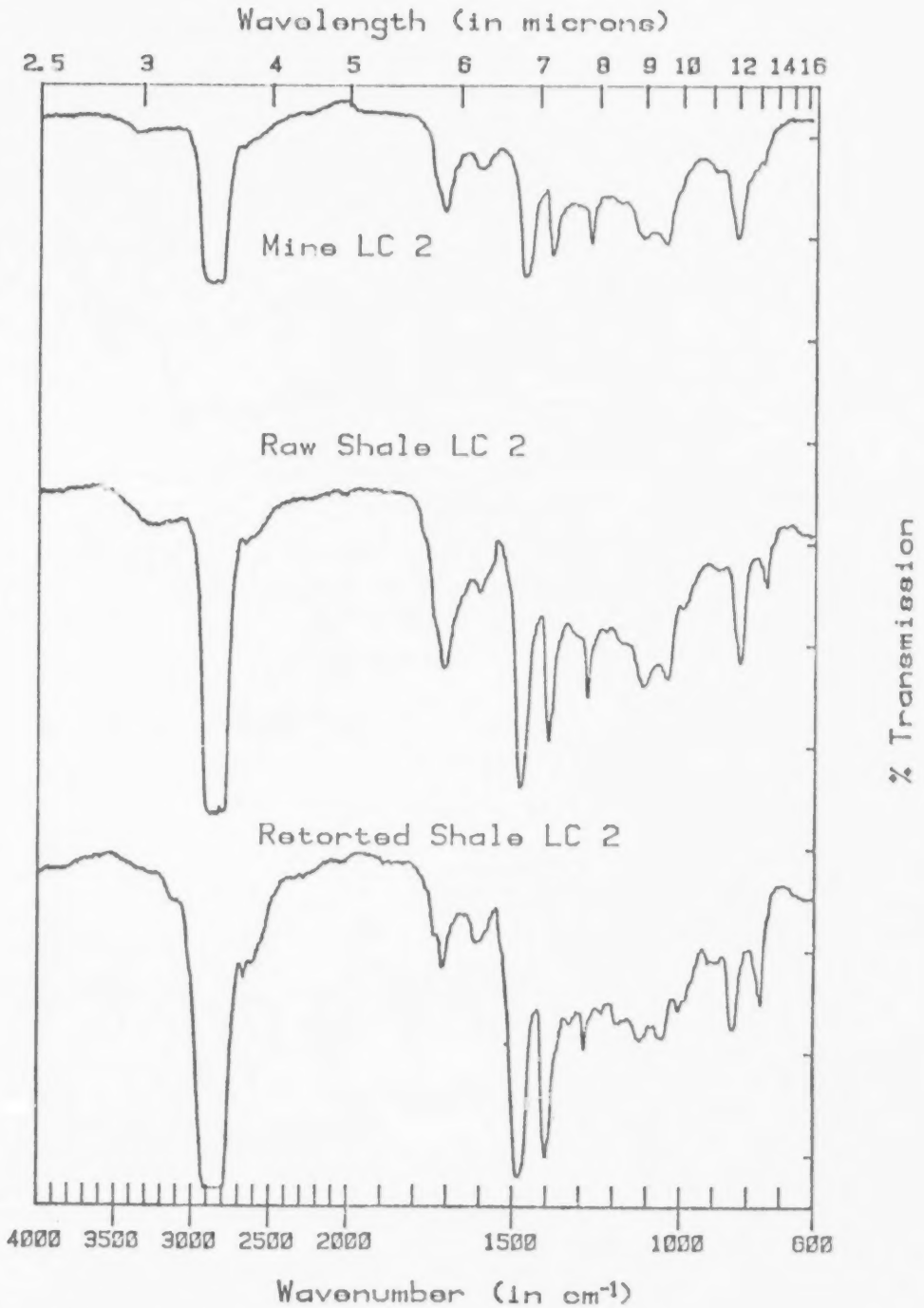

Figure C-2. Infrared spectra of L.C. fraction 2.

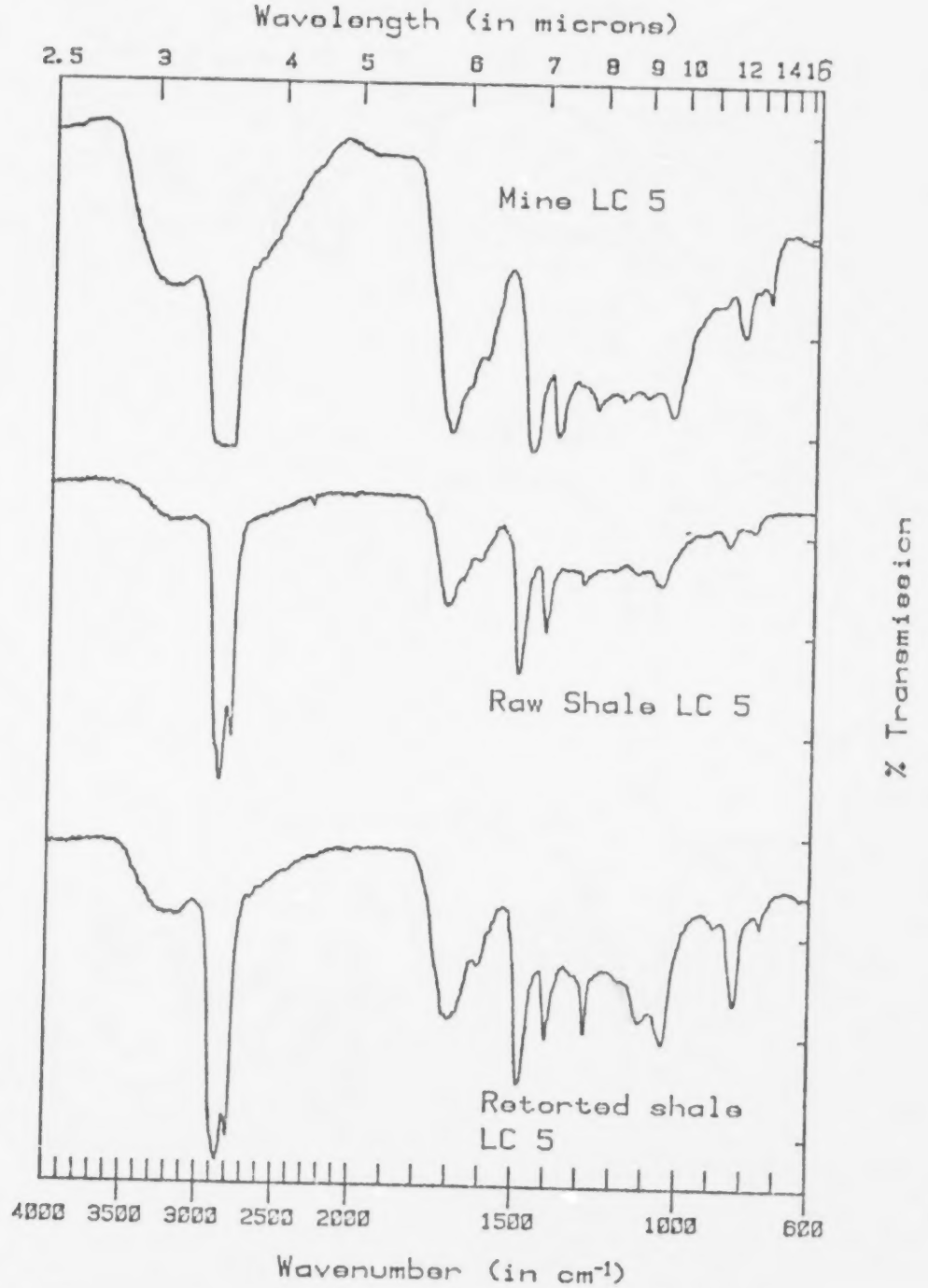

Figure C-3. Infrared spectra of L.C. fraction 5.

TABLE C-1. SUMMARY OF ORGANIC EXTRACTION AND SEPARATION DATA FROM PARTICULATE EMISSIONS: MINE RELATED SAMPLES

Filter no., sampling location, date, starting time, and sampling duration	Sample wt. (g)	Wt. % organic solubles	Wt. % per fraction								
			1	2	3	4	5	6	7	8	9
#502 13 m. into adit 2 run during blast. 9-15,16-77, 1516 hr, 17.7 hr	1.08	3.78	63.2	4.4	5.0	1.7	17.8	3.1	0.4	0.9	3.4
#557 13 m. into adit 1, 9-24-77, 0815 hr, 78.6 hr	3.59	4.95	65.8	3.2	5.2	1.8	14.8	3.7	0.9	0.6	4.0
#588 13 m. into adit 1, run during blast. 9-15,16-77 1514 hr, 17.7 hr	0.89	3.25	42.5	5.2	6.8	3.0	23.2	9.4	2.7	3.9	3.3
#720 13 m. into adit 1 9-24- to 9-27-77, 0815 hr, 78.6 hr	3.57	4.01	64.6	3.2	5.7	2.0	16.1	3.5	0.9	0.7	3.3
#725 13 m. into adit 2 9-27-77, 0811 hr, 78.8 hr	1.91	3.42	63.5	4.2	3.8	1.9	17.1	4.1	1.4	1.7	2.2
#749 10 m. into adit 1 9-7-77, 1430 hr, 1.0 hr	1.17	3.88	59.0	3.7	4.9	2.1	21.7	6.2	0.7	0.3	1.3
#761 13 m. into adit 2 9-7-77, 1200 hr, 1 hr	0.50	3.88	58.0	3.4	4.2	3.3	21.6	2.9	1.7	2.4	2.4

TABLE C-2. SUMMARY OF ORGANIC EXTRACTION AND SEPARATION DATA FROM PARTICULATE EMISSIONS: SAMPLES FROM RAW SHALE CRUSHING AND HANDLING AREAS

Filter no., sampling location, date, starting time, and sampling duration	Sample wt. (g)	Wt. % organic solubles	Wt. % per fraction								
			1	2	3	4	5	6	7	8	9
#754 10 m. N of crusher at loader. 9-4-77, 0910 hr. 6.5 hr	1.85	1.74	33.5	4.4	4.7	1.7	25.0	20.6	3.8	5.7	0.6
#745 5 m. N of screening room baghouse discharge. 9-7,8-77, 1630 hr, 23.0 hr	43.99	1.40	43.9	10.2	2.7	0.7	32.4	5.6	0.4	0.4	3.7
#733 screening room baghouse discharge, 9-8,9-77 1630 hr, 17.2 hr	21.76	0.08	35.4	6.9	14.5	3.9	22.2	9.2	1.7	3.1	3.1
#777 screening room baghouse discharge 9-9,10-77 0930 hr, 19.2 hr	24.32	0.07	36.8	8.9	7.7	4.0	14.3	16.7	2.8	4.7	4.0
#564 near electrical shed 9-24-77, 1121 hr 18.3 hr	21.32	1.41	39.1	9.4	3.6	0.8	25.4	20.7	0.7	0.4	1.3

(continued)

TABLE C-2. SUMMARY OF ORGANIC EXTRACTION AND SEPARATION DATA FROM PARTICULATE EMISSIONS: SAMPLES FROM RAW SHALE CRUSHING AND HANDLING AREAS (continued)

Filter no., sampling location, date, starting time, and sampling duration	Sample wt. (g)	Wt. % organic solubles	Wt. % per fraction								
			1	2	3	4	5	6	7	8	9
Filter 3 5 m. n of screening room baghouse discharge 9-13, 14-77, 0825 hr, 26.3 hr	3.79**	1.66	29.8	6.1	5.2	1.7	28.4	30.8	1.7	1.6	4.7
Filter 6 5 m. N of screening room baghouse discharge 9-14, 15-77, 1300 hr, 27.0 hr	2.31**	1.61	29.6	7.0	4.9	2.4	32.5	14.9	2.1	2.6	4.0
DRI AP VI screening room dust samples collected 3-15,16,17-76 during previous sampling program	200.00	1.54	44.0	6.5	3.2	1.2	20.2	19.8	1.2	1.2	2.7

**Only a small part of total sample was available for extraction.

TABLE C-3. SUMMARY OF ORGANIC EXTRACTION AND SEPARATION DATA FROM PARTICULATE EMISSIONS: SAMPLES FROM RETORTED SHALE HANDLING AREAS

Filter no., sampling location, date, starting time, and sampling duration	Sample wt. (g)	Wt. % organic solubles	Wt. % per fraction								
			1	2	3	4	5	6	7	8	9
#597 5 m. Ne of retorted shale baghouse discharge. 9-5,6-77, 1300 hr, 20.3 hr	11.90	0.45	33.2	2.6	6.6	6.2	32.5	12.2	1.7	1.3	2.6
#598 5 m. Sw of retorted shale baghouse discharge 9-9,10-77, 0940 hr 21.5 hr.	6.19	0.43	25.1	3.4	5.4	6.4	27.8	17.8	3.8	5.7	4.6
#751 5 m. N of retorted shale baghouse discharge. 9-7,8-77, 1023 hr. 19.6 hr	10.81	0.48	43.1	6.0	4.0	1.6	23.7	11.3	3.5	3.4	3.5
#784 5 m. N of retorted shale baghouse discharge 9-6-77, 0930 hr, 5.0 hr	17.48	0.52	37.8	4.4	6.1	6.1	22.3	14.4	3.2	4.4	1.4
#742 5 m. Nw of retorted shale baghouse dispenser. 9-8,9-77, 0920 hr, 24.3 hr	12.29	0.47	28.1	6.1	5.1	3.1	34.5	13.7	3.5	2.5	3.5

(continued)

TABLE C-3. SUMMARY OF ORGANIC EXTRACTION AND SEPARATION DATA FROM PARTICULATE EMISSIONS: SAMPLES FROM RETORTED SHALE HANDLING AREAS (continued)

Filter no., dampling location, date, starting time, and sampling duration	Sample wt. (g)	Wt. % organic solubles	Wt. % per fraction								
			1	2	3	4	5	6	7	8	9
#724 next to 1st lower transfer of retorted shale conveyor. 9-26, 27-77, 1810 hr, 14.5 hr.	23.93	0.27	48.4	5.3	5.9	2.2	24.4	10.6	1.2	1.6	0.5
#723 next to 1st lower transfer of retorted shale conveyor. 9-26, 27-77, 1812 hr, 14.5 hr	22.42	0.22	50.6	4.7	3.0	1.8	25.5	7.5	1.0	2.7	3.0
DRI AP V 2 m. SE of the screw conveyor chute (upper level)pilot plant retorted shale belt 3-9,10-76, during previous sampling program.	100.00	1.33	43.2	7.0	4.5	1.5	26.3	11.5	1.5	1.5	3.0